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Annotated List of the Leaf Beetles (Coleoptera: Chrysomelidae) of Kentucky: Subfamily Eumolpinae

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ABSTRACT

An examination of leaf beetle specimens (Coleoptera: Chrysomelidae) in the largest beetle collections in Kentucky, recent inventory work in state nature preserves and other protected areas, and a review of the literature revealed forty-six species of the subfamily Eumolpinae present in Kentucky, twenty of which previously were unreported for the state. Distribution maps and label data are presented for the forty-six Kentucky species, including spatial (state and Kentucky county records), temporal (years and months of collection in Kentucky), and plant association information. The following species are reported from Kentucky for the first time: *Metachroma carolinense* Blake, *Metachroma laterale* Crotch, *Metachroma orientale* Blake, *Graphops curtipennis curtipennis* (F. E. Melsheimer), *Graphops marcassita marcassita* (Crotch), *Graphops simplex* J. L. LeConte, *Graphops varians* J. L. LeConte, *Paria fragariae* Wilcox, *Paria pratensis* Balsbaugh, *Paria sellata* (Horn), *Colaspis favosa* Say, *Colaspis suilla suilla* F., *Glyptoscelis pubescens* (F.), *Spintherophyta globosa* (Olivier), *Tymnes metasternalis* (Crotch), *Tymnes violaceus* Horn, *Demotina modesta* Baly, *Fidia longipes* (F. E. Melsheimer), *Xanthonia angulata* Staines & Weisman, and *Xanthonia serrata* Staines & Weisman.

KEY WORDS: Kentucky, leaf beetles, Chrysomelidae, Eumolpinae, biodiversity, new state records

INTRODUCTION

This paper is the sixth in a series intended to present a synopsis of the historical collection data on leaf beetles (Coleoptera: Chrysomelidae) from the major Coleoptera collections in Kentucky and augment these data with new information gained from recent monitoring in state preserves and other protected locations. The first five papers presented information on the subfamilies Cassidinae (Barney et al. 2007), Donaciinae and Criocerinae (Barney et al. 2008a), Chrysomelinae (Barney et al. 2008b), tribes Galerucini and Luperini (Galerucinae) (Barney et al. 2009a), and Alticini (Galerucinae) (Barney et al. 2009b).

Many of the genera have been revised, including *Xanthonia* (Staines and Weisman 2001), *Fidia* (Strother and Staines 2008), *Paria* (Wilcox 1957; Balsbaugh 1970), *Glyptoscelis* (Blake 1967), *Metachroma* (Blake 1970), and *Colaspis* (in part, Blake 1974).

The purpose of this study is to present historical and current knowledge of the distribution, abundance, and plant associations of eumolpine leaf beetles in Kentucky.

MATERIALS AND METHODS

To establish a historical perspective, leaf beetle specimens from the major insect collections in Kentucky (and from collections located in other states but known to contain Kentucky specimens) were examined, reidentified, and their label data recorded. The following collections were studied with the timeframe of their Kentucky specimens listed:

CMC	Cincinnati Museum Center, Cincinnati, OH	1871–1931

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UKIC	University of Kentucky Insect Collection, Lexington, KY	1889–1993
WKUC	Western Kentucky University Collection, Bowling Green, KY	1958–2006
RJBC	Robert J. Barney Collection, Frankfort, KY (private)	1983–2009
BYUC	Brigham Young University Collection, Provo, UT	1988–1999
CWC	Charles Wright Collection, Frankfort, KY (private)	1991–2009
KYSU	Kentucky State University Collection, Frankfort, KY	2004–2009

The Cincinnati Museum Collection, formerly known as the Cincinnati Museum of Natural History, houses the Charles Dury Collection, comprising approximately 75,000 insect specimens primarily collected in the Cincinnati/northern Kentucky area (Vulinec and Davis 1984). Specimens from this collection are usually labeled as "Ky. near Cin. O." with no county or date information provided. We designate these specimens as "ca. 1900" because most of the collecting was done around the turn of the century.

The Kentucky State University Insect Collection is primarily the specimens generated by the Kentucky Leaf Beetle Biodiversity Project. We currently are conducting extensive collecting in many grass-dominated barrens and rock outcrop (glade) communities that are known for possessing uncommon plants and plant associations (Jones 2005) and have never been surveyed for leaf beetles. These sites are managed by the Kentucky State Nature Preserves Commission, The Nature Conservancy, and the United States Army at Fort Campbell Military Reservation (Baskin et al. 1994). Most specimens were collected via sweep net by the senior author within five state nature preserves in 2004–2009 and Fort Campbell in 2008–2009: Crooked Creek Barrens (Lewis County) and Blue Licks Battlefield (Robertson County) in northeastern Kentucky, Eastview Barrens (Hardin County) and Thompson Creek Glades (LaRue County) in central Kentucky, and Raymond Athey Barrens (Logan County) and Fort Campbell (Christian and Trigg Counties) in western Kentucky.

For each eumolpine species documented for Kentucky, the following data are presented: state-level distribution in the United States (from Riley et al. 2003), Kentucky county records, abundance by year and month in Kentucky, and specimens per collection. Other pertinent information present on specimen labels, such as the method of collection and plant association information, is presented in the "Comments" section for each species. This information provides the opportunity to help determine abundance, seasonality, and distribution from a historical perspective. One should note that plant collection records taken from specimen labels are notoriously inaccurate and may not reflect true host plants (Clark et al. 2004).

RESULTS

According to the "Catalog of Leaf Beetles of America North of Mexico" (Riley et al. 2003), there are 75 species of Eumolpinae recorded in at least one of the seven states contiguous to Kentucky, and Strother and Staines (2008) described an additional *Fidia* species. However, only 25 species were reported from Kentucky. An examination of over 2700 eumolpine leaf beetle specimens from the major collections in the state and others known to contain Kentucky specimens, plus a review of certain publications, revealed 46 species (42 observed and four additional documented from the literature) of the 76 recorded in Riley et al. (2003) and Strother and Staines (2008), including 20 new state records (Table 1). A breakdown of specimens, species and records by collection examined is presented in Table 2.

Metachroma carolinense Blake (Figure 1A) (new state record)

Kentucky County: Nelson
Year: 2009 (1)
Month: July (1)
Abundance: 1 specimen: 1-KYSU
Comments: One specimen was collected on Golden Eagle Ridge at Bernheim Forest.

Metachroma laterale Crotch (Figure 1B) (new state record)

Kentucky County: Trigg
Year: 2009 (1)
Month: May (1)
Abundance: 1 specimen: 1-KYSU
Comments: One specimen was collected at Fort Campbell. Clark et al. (2004) reported

Table 1. List of Eumolpinae (Coleoptera: Chrysomelidae) recorded from Kentucky, with number of Kentucky specimens examined, number of Kentucky county records, range of years of collection in Kentucky, and new state records.

Species	Specimens Examined
Metachroma carolinense Blake	1 specimen: 1 county, 2009 (new state record)
Metachroma laterale Crotch	1 specimen: 1 county, 2009 (new state record)
Metachroma magnipunctatum Blake	unknown
Metachroma orientale Blake	2 specimens: 2 counties, 2005–2008 (new state record)
Metachroma pallidum (Say)	14 specimens: 3 counties, 2004–2009
Graphops curtipennis curtipennis (F. E. Melsheimer)	59 specimens: 6 counties, 1892–2009 (new state record)
Graphops marcassita marcassita (Crotch)	21 specimens: 8 counties, ca. 1900–2009 (new state record)
Graphops pubescens (F. E. Melsheimer)	4 specimens: 3 counties, 1937–2008
Graphops simplex J. L. LeConte	7 specimens: 2 counties, 2005–2008 (new state record)
Graphops varians J. L. LeConte	28 specimens: 5 counties, 2005–2009 (new state record)
Paria fragariae/pratensis complex	232 specimens: 19 counties, 1890–2009 (new state records)
Paria quadrinotata (Say)	95 specimens: 10 counties, 1894–2008
Paria scutellaris (Notman)	15 specimens: 9 counties, 1976–2006
Paria sellata (Horn)	94 specimens: 10 counties, 1889–2009 (new state record)
Paria sexnotata (Say)	71 specimens: 17 counties, 1971–2009
Paria thoracica (F. E. Melsheimer)	309 specimens: 25 counties, 1893–2008
Typophorus nigritus viridicyaneus (Crotch)	45 specimens: 6 counties, 1967–2008
Brachypnoea clypealis (Horn)	199 specimens: 22 counties, 1889–2008
Brachypnoea convexa (Say)	6 specimens: 3 counties, 1996–2007
Brachypnoea margaretae (Schultz)	684 specimens: 41 counties, 1889–2008
Brachypnoea puncticollis (Say)	208 specimens: 7 counties, 1944–2009
Brachypnoea tristis (Olivier)	47 specimens: 20 counties, 1952–2008
Colaspis brunnea (F.)	346 specimens: 27 counties, 1949–2008
Colaspis favosa Say	1 specimen: 1 county, 2008 (new state record)
Colaspis suilla suilla F.	1 specimen: 1 county, 2005 (new state record)
Glyptoscelis barbata (Say)	unknown
Glyptoscelis pubescens (F.)	4 specimens: 4 counties, 1892–2005 (new state record)
Myochrous denticollis (Say)	42 specimens: 10 counties, ca. 1900–2006
Rhabdopterus deceptor Barber	1 specimen: 1 county, 2005
Rhabdopterus praetextus (Say)	6 specimens: 4 counties, 1995–2008
Spintherophyta globosa (Olivier)	2 specimens: 2 counties, 1988–1990 (new state record)
Tymnes metasternalis (Crotch)	5 specimens: 2 counties, 1971–2009 (new state record)
Tymnes tricolor (F.)	6 specimens: 4 counties, ca. 1900–2004
Tymnes violaceus Horn	2 specimens: 1 county, 2004–2005 (new state record)
Chrysochus auratus (F.)	105 specimens: 26 counties, 1892–2009
Demotina modesta Baly	16 specimens: 2 counties, 2007–2008 (new state record)
Fidia confusa Strother	unknown
Fidia longipes (F. E. Melsheimer)	6 specimens: 4 counties, 1971–2005 (new state record)
Fidia rileyorum Strother	2 specimens: 1 county, 2006
Fidia viticida Walsh	2 specimens: 1 county, 1998
Xanthonia angulata Staines & Weisman	1 specimen: 1 county, 2005 (new state record)
Xanthonia decemnotata (Say)	4 specimens: 3 counties, 1982–2003
Xanthonia serrata Staines & Weisman	1 specimen: 1 county, 2009 (new state record)
Xanthonia striata Staines & Weisman	unknown
Xanthonia villosula (F. E. Melsheimer)	7 specimens: 3 counties, 1907–2009

Table 2. The number of specimens, species and new Kentucky state records of eumolpinae beetles (Coleoptera: Chrysomelidae) found in the largest leaf beetle collections from Kentucky.

Collection	Specimens	Species	Records
Kentucky State University Collection	1605	37	10
University of Kentucky Insect Collection	856	21	7
Charles Wright Collection	90	15	0
Brigham Young University Collection	83	16	2
Robert J. Barney Collection	48	11	0
Western Kentucky University Collection	12	6	0
Cincinnati Museum Center	9	4	1
Totals	2703	42	20

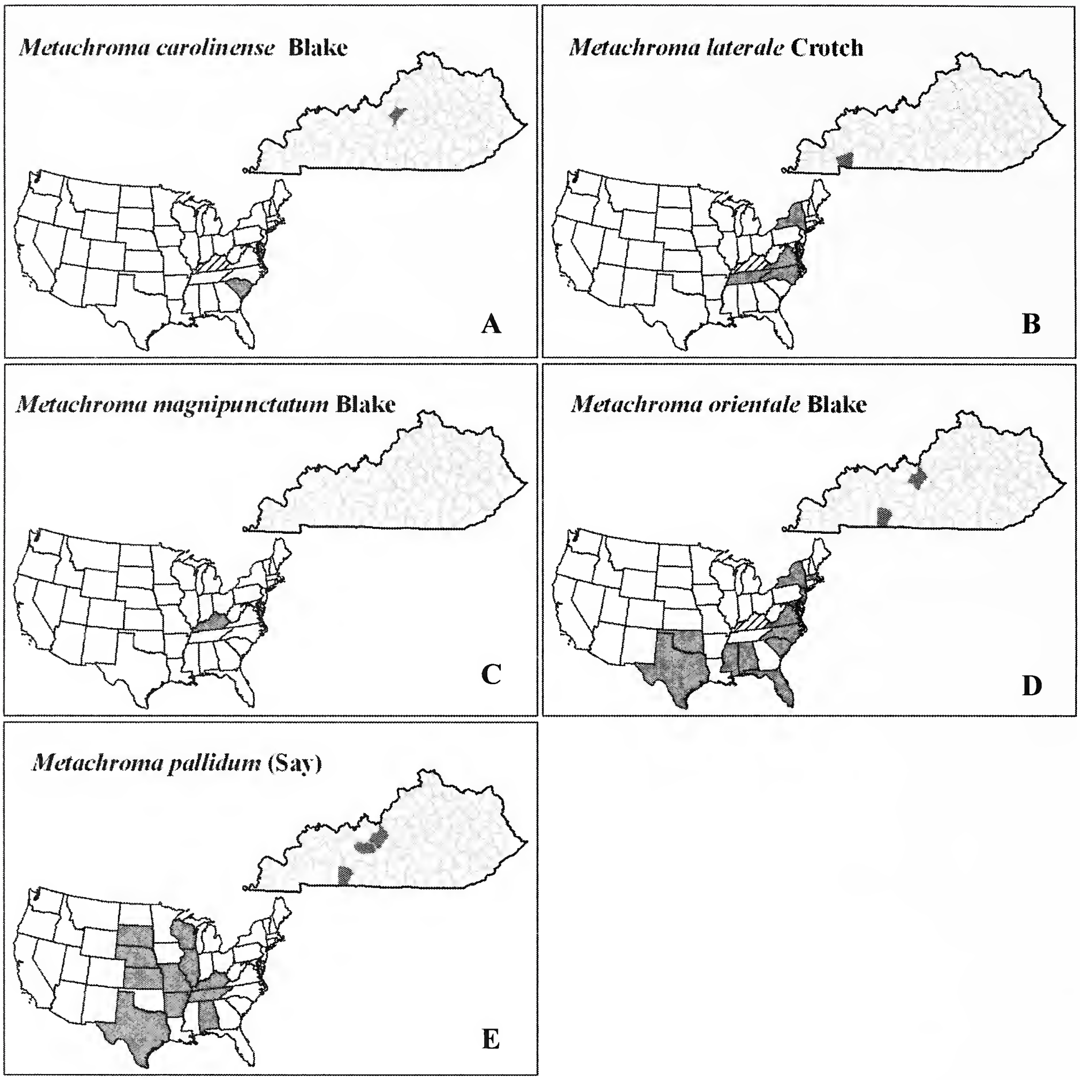

Figure 1. The known distribution of Eumolpinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

this species associated with *Quercus* (Fagaceae).

Metachroma magnipunctatum Blake (Figure 1C)

Kentucky Counties: unknown
Years: unknown
Months: unknown
Abundance: unknown
Comments: Blake (1970) reported the type-locality for this species as Kentucky, and stated that there are no other specimens like the two in the G. Frey Museum (Tutzing, Germany) known from the United States.

Metachroma orientale Blake (Figure 1D) (new state record)

Kentucky Counties: Hardin, Logan
Years: 2005 (1), 2008 (1)
Months: June (2)
Abundance: 2 specimens: 2-KYSU
Comments: Both specimens were collected in barren areas of state nature preserves. Clark et al. (2004) reported this species associated with *Quercus* (Fagaceae).

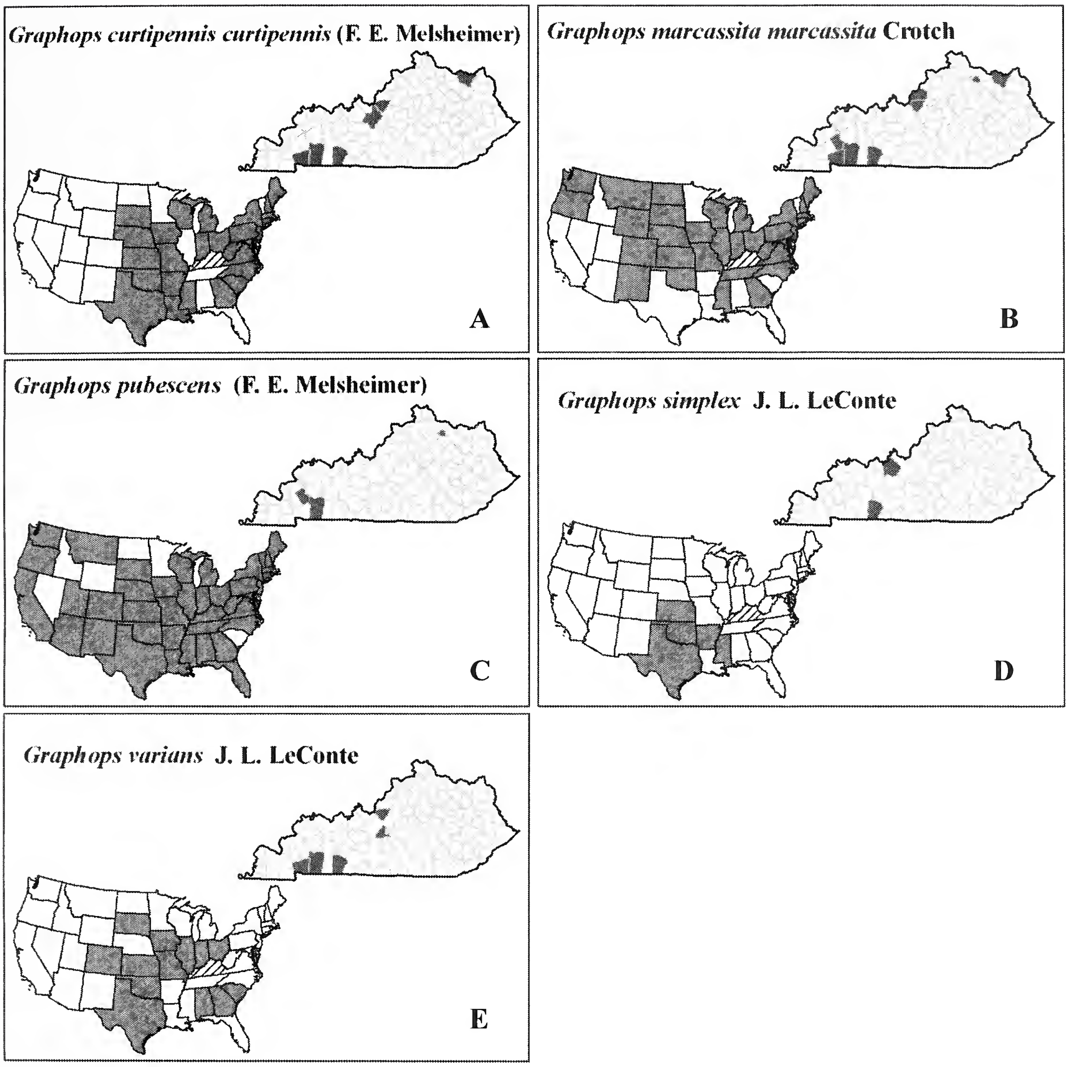

Figure 2. The known distribution of Eumolpinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Metachroma pallidum (Say) (Figure 1E)

Kentucky Counties: Grayson, Hardin, Logan
Years: 2004 (7), 2005 (5), 2007 (1), 2009 (1)
Months: July (13), August (1)
Abundance: 14 specimens: 14-KYSU
Comments: The KYSU specimens were all collected in native barren preserves. Blake (1970) reported this species from Benton (Marshall County).

Graphops curtipennis curtipennis (F. E. Melsheimer) (Figure 2A) (new state record)

Kentucky Counties: Bullitt, Christian, Hardin, Lewis, Logan, Trigg
Years: 1892 (1), 1975 (1), 2004 (2), 2005 (8), 2006 (9), 2007 (5), 2008 (24), 2009 (9)
Months: May (12), June (34), July (13)
Abundance: 59 specimens: 57-KYSU, 2-UKIC
Comments: Clark et al. (2004) reported this species associated with *Hypericum* (Clusiaceae).

Graphops marcassita marcassita (Crotch) (Figure 2B) (new state record)

Kentucky Counties: Bullitt, Caldwell, Christian, Jefferson, Lewis, Logan, Robertson, Trigg

Years: ca. 1900 (1), 1937 (2), 1938 (1), 1940 (3), 2005 (1), 2006 (4), 2007 (1), 2008 (7), 2009 (1)

Months: February (1), March (2), May (2), June (6), July (6), October (3)

Abundance: 21 specimens: 1-CMC, 14-KYSU, 6-UKIC

Comments: A Dury Collection specimen was labeled "Ky. near Cin. O." Clark et al. (2004) reported this species associated with *Fragaria* (Rosaceae).

Graphops pubescens (F. E. Melsheimer) (Figure 2C)

Kentucky Counties: Caldwell, Christian, Robertson

Years: 1937 (1), 2008 (3)

Months: February (1), July (3)

Abundance: 4 specimens: 3-KYSU, 1-UKIC

Comments: Clark et al. (2004) reported this species associated with *Oenothera* (Onagraceae).

Graphops simplex J. L. LeConte (Figure 2D) (new state record)

Kentucky Counties: Breckinridge, Logan

Years: 2005 (1), 2006 (4), 2008 (2)

Months: May (3), June (4)

Abundance: 7 specimens: 7-KYSU

Comments: All but one specimen was collected at Raymond Athey Barrens State Nature Preserve. Clark et al. (2004) reported this species associated with *Oenothera* (Onagraceae).

Graphops varians J. L. LeConte (Figure 2E) (new state record)

Kentucky Counties: Bullitt, Christian, LaRue, Logan, Trigg

Years: 2005 (7), 2006 (6), 2007 (3), 2008 (11), 2009 (1)

Months: May (2), June (9), July (15), August (2)

Abundance: 28 specimens: 28-KYSU

Comments: All specimens were collected in preserved barren habitats. Clark et al. (2004) reported this species associated with *Oenothera* (Onagraceae).

Paria fragariae/pratensis complex (Figure 3A) (new state record)

Kentucky Counties: Breckinridge, Bullitt, Caldwell, Carter, Fayette, Franklin, Grayson, Hardin, Henderson, Henry, Jessamine, LaRue, Lewis, Lincoln, Logan, Pulaski, Robertson, Trigg, Warren

Years: 1890 (32), 1891 (45), 1892 (1), 1903 (1), 1916 (4), 1922 (6), 1929 (1), 1937 (1), 1971 (3), 1973 (1), 1975 (1), 1993 (1), 2003 (3), 2004 (1), 2005 (17), 2006 (50), 2007 (9), 2008 (53), 2009 (2)

Months: February (1), April (14), May (79), June (63), July (38), August (19), September (8), October (2), November (8)

Abundance: 232 specimens: 5-CWC, 131-KYSU, 96-UKIC

Comments: This complex is composed of *P. fragariae* Wilcox and *P. pratensis* Balsbaugh, both of which are state records. Some of the specimens examined are clearly *P. fragariae*, while others are clearly *P. pratensis*, but still others are intermediate or otherwise difficult to assign to one or the other species. Many of the 1890–1891 specimens were labeled as from strawberry beds. Some specimens were collected via Malaise trap. Clark et al. (2004) reported these species associated with Rosaceae.

Paria quadrinotata (Say) (Figure 3B)

Kentucky Counties: Caldwell, Fayette, Hart, Jefferson, Laurel, Marion, Owen, Powell, Rowan, Webster

Years: 1894 (2), 1895 (1), 1912 (1), 1913 (1), 1914 (1), 1937 (1), 1940 (9), 1971 (26), 1975 (3), 1981 (4), 1982 (7), 1988 (29), 1994 (1), 1996 (1), 2003 (1), 2004 (1), 2005 (2), 2008 (4)

Months: February (1), March (1), April (49), May (31), June (3), October (9), December (1)

Abundance: 95 specimens: 8-BYUC, 4-CWC, 5-KYSU, 4-RJBC, 74-UKIC

Comments: Many specimens were collected via Malaise trap. Clark et al. (2004) reported this species associated with *Juglans* (Juglandaceae).

Paria scutellaris (Notman) (Figure 3C)

Kentucky Counties: Franklin, Grayson, Hancock, Henry, Jefferson, Menifee, Owsley, Pike, Powell

Years: 1976 (2), 1994 (1), 1996 (2), 2002 (1), 2003 (6), 2004 (2), 2006 (1)

Months: March (2), May (5), June (7), August (1)

Abundance: 15 specimens: 1-BYUC, 10-CWC, 1-KYSU, 3-RJBC

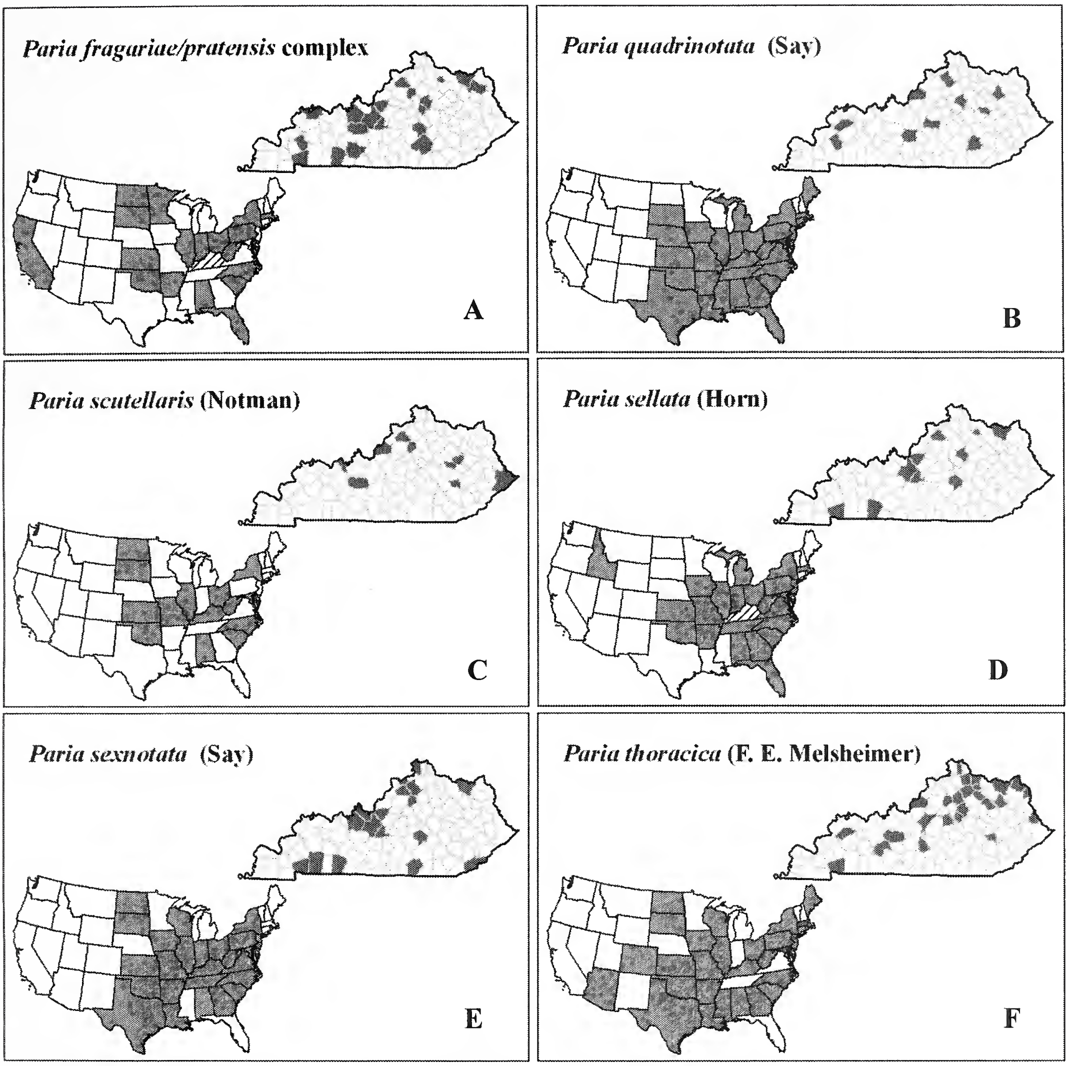

Figure 3. The known distribution of Eumolpinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Comments: Clark et al. (2004) reported this species associated with *Cornus* (Cornaceae).

Paria sellata (Horn) (Figure 3D) (new state record)

Kentucky Counties: Bullitt, Fayette, Hardin, Henry, LaRue, Lewis, Lincoln, Logan, Robertson, Trigg

Years: 1889 (1), 1983 (1), 2003 (1), 2004 (7), 2005 (20), 2006 (8), 2007 (12), 2008 (32), 2009 (12)

Months: May (23), June (54), July (16), August (1)

Abundance: 94 specimens: 1-CWC, 91-KYSU, 1-RJBC, 1-UKIC

Comments: Several long series of specimens were taken on *Hypericum dolabriforme* (Clusiaceae).

Paria sexnotata (Say) (Figure 3E)

Kentucky Counties: Boone, Breckinridge, Bullitt, Carroll, Christian, Franklin, Hardin, Harlan, Henry, LaRue, Lewis, Lincoln, Logan, Meade, Owen, Trigg, Wayne

Years: 1971 (1), 1972 (1), 1974 (3), 1989 (1), 1993 (1), 1994 (1), 1996 (2), 2001 (1), 2003

(2), 2004 (4), 2005 (12), 2006 (16), 2007 (7), 2008 (17), 2009 (2)

Months: April (6), May (33), June (17), July (7), August (7), September (1)

Abundance: 71 specimens: 1-BYUC, 10-CWC, 55-KYSU, 5-UKIC

Comments: Clark et al. (2004) reported this species associated with *Juniperus* (Cupressaceae).

Paria thoracica (F. E. Melsheimer) (Figure 3F)

Kentucky Counties: Bath, Boyd, Bracken, Butler, Fayette, Franklin, Grayson, Green, Greenup, Harrison, Jefferson, Jessamine, Kenton, Lewis, Martin, Mercer, Nelson, Nicholas, Owsley, Pendleton, Robertson, Rowan, Scott, Trigg, Webster

Years: 1893 (1), 1916 (4), 1917 (2), 1918 (1), 1920 (3), 1924 (3), 1945 (1), 1948 (1), 1959 (4), 1970 (1), 1971 (7), 1972 (1), 1976 (5), 1979 (2), 1983 (7), 1985 (2), 1992 (1), 1994 (1), 1995 (2), 1996 (1), 1998 (5), 1999 (1), 2001 (1), 2003 (5), 2004 (6), 2005 (48), 2006 (78), 2007 (53), 2008 (62)

Months: March (3), May (57), June (165), July (79), August (5)

Abundance: 309 specimens: 8-BYUC, 12-CWC, 242-KYSU, 15-RJBC, 32-UKIC

Comments: Clark et al. (2004) reported this species associated with Asteraceae.

Typophorus nigritus viridicyaneus (Crotch) (Figure 4A)

Kentucky Counties: Ballard, Bullitt, Franklin, Logan, Monroe, Trigg

Years: 1967 (1), 1976 (1), 2005 (13), 2006 (13), 2007 (7), 2008 (10)

Months: May (1), June (23), July (20), August (1)

Abundance: 45 specimens: 1-CWC, 41-KYSU, 1-RJBC, 2-WKUC

Comments: Clark et al. (2004) reported this species associated with Convolvulaceae.

Brachypnoea clypealis (Horn) (Figure 4B)

Kentucky Counties: Boyd, Bracken, Breathitt, Bullitt, Carter, Casey, Clark, Franklin, Green, Greenup, Hardin, Henry, Jessamine, LaRue, Lee, Lewis, Logan, Madison, Ohio, Pulaski, Robertson, Russell

Years: 1889 (12), 1890 (1), 1891 (17), 1892 (3), 1893 (11), 1894 (11), 1917 (7), 1942 (2), 1944 (3), 1945 (2), 1946 (2), 1970 (2), 1971 (3), 1972 (1), 1988 (1), 1993 (4), 1994 (1), 1995 (3), 1998 (8), 2001 (1), 2003 (12), 2004 (5), 2005 (43), 2006 (19), 2007 (24), 2008 (1)

Months: June (67), July (109), August (17), September (5), October (1)

Abundance: 199 specimens: 16-BYUC, 14-CWC, 84-KYSU, 8-RJBC, 77-UKIC

Comments: Clark et al. (2004) reported this species associated with Asteraceae.

Brachypnoea convexa (Say) (Figure 4C)

Kentucky Counties: Franklin, Henry, Logan

Years: 1996 (3), 2006 (2), 2007 (1)

Months: June (2), July (4)

Abundance: 6 specimens: 3-CWC, 3-KYSU

Brachypnoea margaretae (Schultz) (Figure 4D)

Kentucky Counties: Ballard, Bourbon, Boyd, Breathitt, Bullitt, Calloway, Clay, Crittenden, Daviess, Fayette, Fulton, Garrard, Graves, Grayson, Hardin, Henderson, Henry, Jessamine, LaRue, Lee, Lewis, Lincoln, Lyon, McLean, Meade, Mercer, Ohio, Owsley, Pendleton, Perry, Pike, Pulaski, Robertson, Rowan, Scott, Simpson, Spencer, Trigg, Warren, Webster, Woodford

Years: 1889 (6), 1890 (5), 1891 (19), 1892 (10), 1893 (16), 1894 (28), 1895 (8), 1912 (4), 1920 (2), 1924 (2), 1926 (1), 1941 (2), 1945 (1), 1947 (5), 1968 (3), 1969 (1), 1970 (59), 1971 (40), 1972 (77), 1974 (4), 1975 (1), 1976 (1), 1983 (3), 1995 (4), 1997 (1), 2003 (7), 2004 (22), 2005 (50), 2006 (152), 2007 (106), 2008 (44)

Months: April (4), May (26), June (375), July (262), August (16), October (1)

Abundance: 684 specimens: 5-BYUC, 8-CWC, 373-KYSU, 3-RJBC, 292-UKIC, 3-WKUC

Comments: Many specimens were collected via Malaise trap.

Brachypnoea puncticollis (Say) (Figure 4E)

Kentucky Counties: Bullitt, Hardin, LaRue, Lincoln, Logan, Marion, Muhlenburg

Years: 1944 (38), 1993 (1), 2005 (45), 2006 (43), 2007 (57), 2008 (23), 2009 (1)

Months: May (169), June (38), July (1)

Abundance: 208 specimens: 1-CWC, 169-KYSU, 38-UKIC

Brachypnoea tristis (Olivier) (Figure 4F)

Kentucky Counties: Barren, Bracken, Carter, Christian, Clark, Franklin, Grayson, Green, Greenup, Hardin, Henry, Lewis,

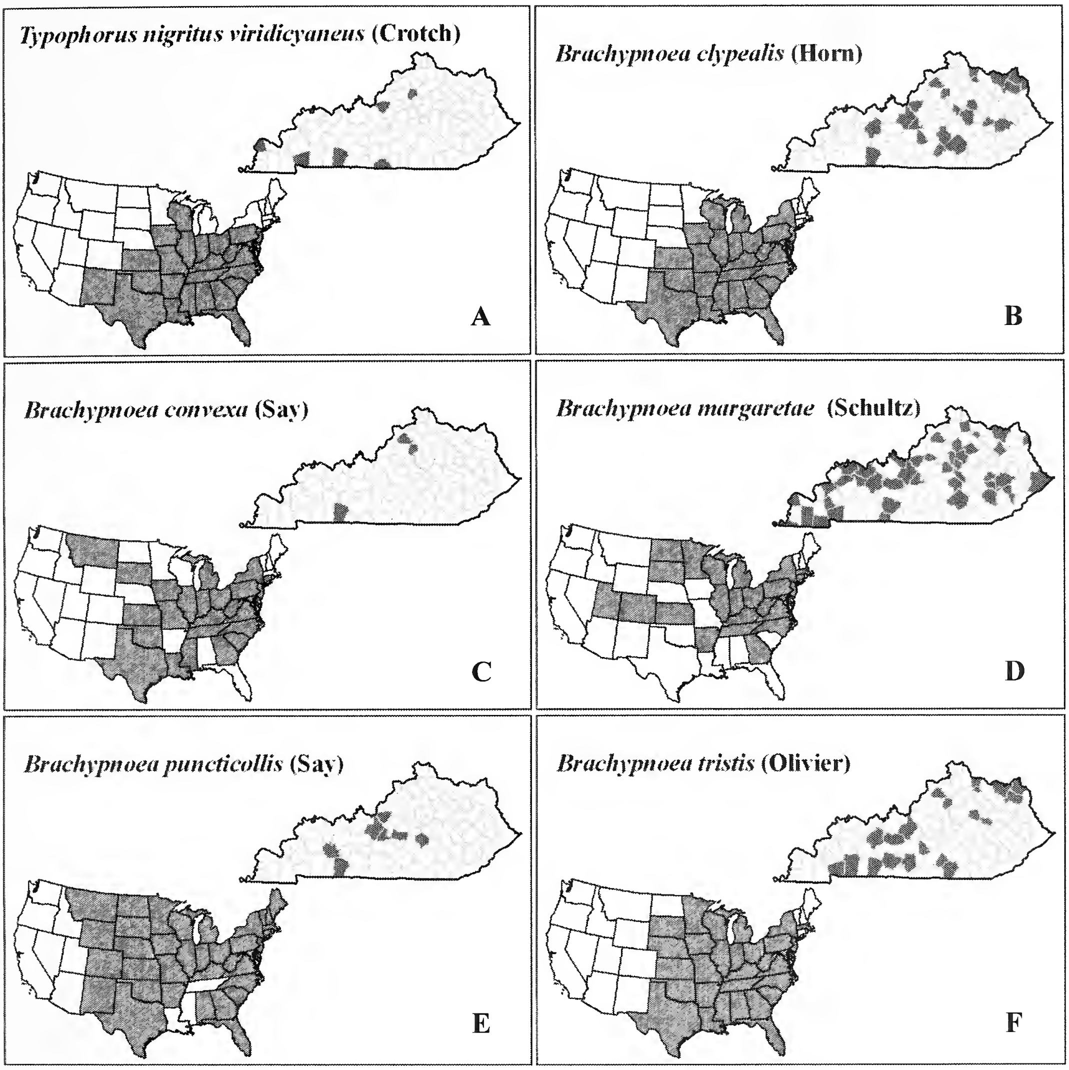

Figure 4. The known distribution of Eumolpinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Logan, Ohio, Powell, Robertson, Russell, Trigg, Warren, Wayne

Years: 1952 (1), 1968 (1), 1987 (7), 1993 (2), 1994 (1), 1995 (1), 1998 (3), 2003 (6), 2005 (12), 2006 (2), 2007 (6), 2008 (5)

Months: June (18), July (28), August (1)

Abundance: 47 specimens: 13-BYUC, 7-CWC, 25-KYSU, 1-UKIC, 1-WKUC

Comments: Many specimens were collected on *Salix* (Salicaceae).

Colaspis brunnea (F.) (Figure 5A)

Kentucky Counties: Bracken, Breathitt, Breckinridge, Carlisle, Casey, Clay, Crittenden, Fayette, Franklin, Fulton, Grant, Graves, Grayson, Hardin, Hart, Henry, LaRue, Lewis, Logan, Morgan, Nelson, Robertson, Rockcastle, Russell, Simpson, Taylor, Trigg

Years: 1949 (9), 1962 (1), 1970 (2), 1971 (127), 1972 (15), 1974 (7), 1998 (3), 2004 (14), 2005 (27), 2006 (95), 2007 (31), 2008 (15)

Months: May (1), June (64), July (245), August (35), September (1)

Abundance: 346 specimens: 3-BYUC, 181-KYSU, 160-UKIC, 2-WKUC

Comments: Many specimens were collected via Malaise trap in the 1970s. Clark et al.

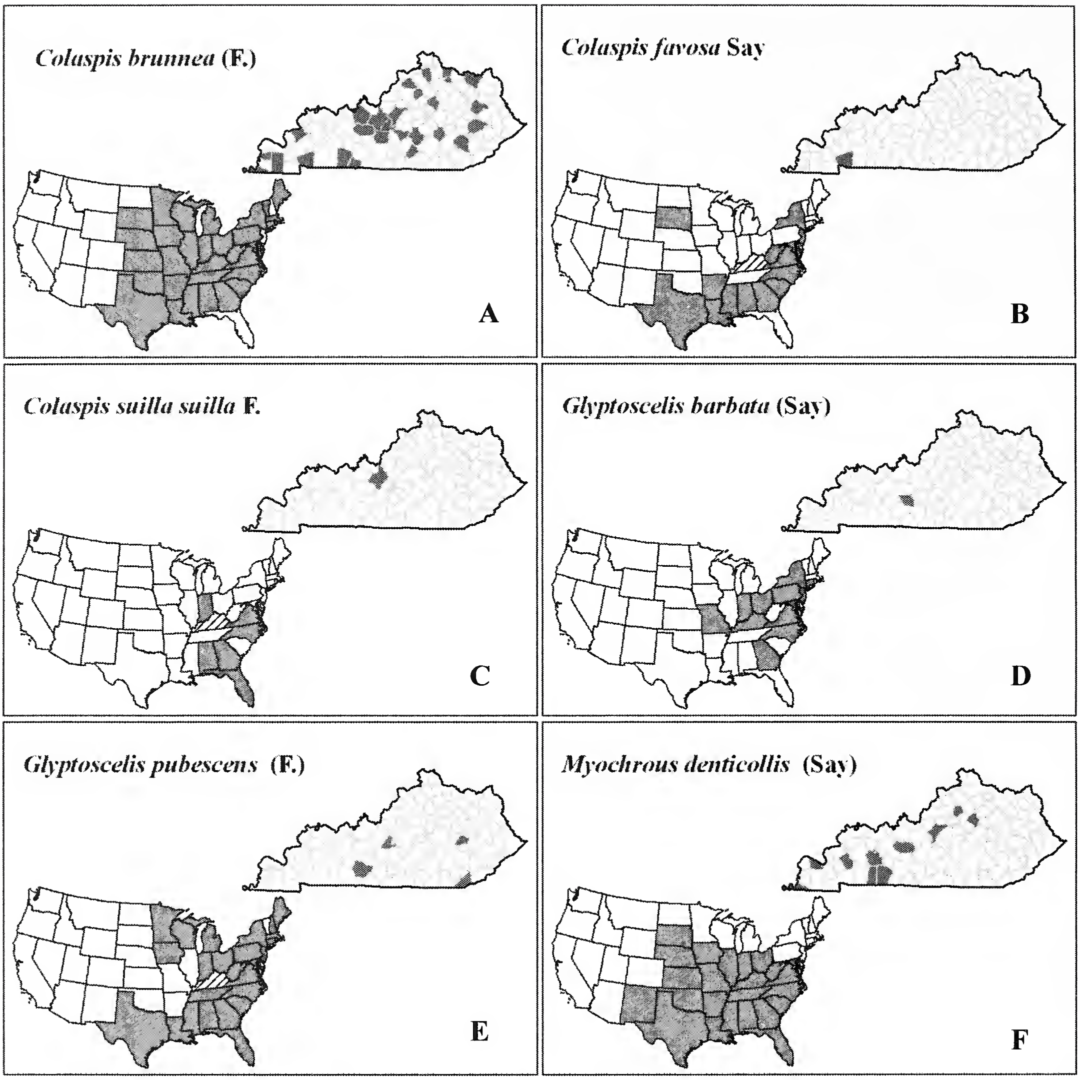

Figure 5. The known distribution of Eumolpinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

(2004) reported this species associated with Fabaceae.

Colaspis favosa Say (Figure 5B) (new state record)

Kentucky County: Trigg
Year: 2008 (1)
Month: June (1)
Abundance: 1 specimen: 1-KYSU
Comments: One specimen was collected at Fort Campbell on June 18, 2008.

Colaspis suilla suilla F. (Figure 5C) (new state record)

Kentucky County: Hardin
Year: 2005 (1)
Month: July (1)
Abundance: 1 specimen: 1-KYSU
Comments: One specimen was collected at Eastview Barrens State Nature Preserve on July 7, 2005.

Glyptoscelis barbata (Say) (Figure 5D)

Kentucky County: Edmonson
Year: 1900
Month: July
Abundance: unknown

Comments: Blake (1967) reported this species from Edmonson County (July 17, 1900).

Glyptoscelis pubescens (F.) (Figure 5E) (new state record)

Kentucky Counties: Bell, LaRue, Lee, Warren
Years: 1892 (1), 1964 (1), 2002 (1), 2005 (1)
Months: May (2), June (1), July (1)
Abundance: 4 specimens: 1-CWC, 1-KYSU, 1-UKIC, 1-WKUC

Myochrous denticollis (Say) (Figure 5F)

Kentucky Counties: Caldwell, Fayette, Franklin, Fulton, Grayson, Logan, McCracken, Muhlenburg, Nelson, Todd
Years: ca. 1900 (3), 1930 (19), 1937 (4), 1948 (7), 1959 (1), 1981 (1), 1983 (1), 1987 (1), 1988 (4), 2006 (1)
Months: March (4), April (1), May (30), June (3), July (1)
Abundance: 42 specimens: 3-CMC, 1-KYSU, 2-RJBC, 36-UKIC
Comments: Three specimens in the Dury collection are labeled "Ky.," with "Lec." as collector. Clark et al. (2004) reported this species associated with Pinaceae.

Rhabdopterus deceptor Barber (Figure 6A)

Kentucky County: Franklin
Year: 2005 (1)
Month: June (1)
Abundance: 1 specimen: 1-RJBC

Rhabdopterus praetextus (Say) (Figure 6B)

Kentucky Counties: Carter, LaRue, Lincoln, Logan
Years: 1995 (1), 2007 (4), 2008 (1)
Months: May (4), June (1), August (1)
Abundance: 6 specimens: 1-BYUC, 5-KYSU

Spintherophyta globosa (Olivier) (Figure 6C) (new state record)

Kentucky Counties: Rowan, Whitley
Years: 1988 (1), 1990 (1)
Months: May (2)
Abundance: 2 specimens: 2-BYUC

Tymnes metasternalis (Crotch) (Figure 6D) (new state record)

Kentucky Counties: Jefferson, Logan
Years: 1971 (1), 2005 (1), 2006 (1), 2007 (1), 2009 (1)
Months: May (2), June (3)
Abundance: 5 specimens: 4-KYSU, 1-UKIC

Tymnes tricolor (F.) (Figure 6E)

Kentucky Counties: Bullitt, Hardin, Jefferson, Rowan
Years: ca. 1900 (1), 1945 (1), 1971 (1), 1976 (1), 1995 (1), 2004 (1)
Months: March (1), June (3), August (1)
Abundance: 6 specimens: 1-BYUC, 1-CMC, 1-KYSU, 1-RJBC, 2-UKIC
Comments: One specimen in Dury collection is labeled "Ky. near Cin. O."

Tymnes violaceus Horn (Figure 6F) (new state record)

Kentucky County: Hardin
Years: 2004 (1), 2005 (1)
Months: May (1), June (1)
Abundance: 2 specimens: 2-KYSU
Comments: Both specimens were collected in Jim Scudder State Nature Preserve.

Chrysochus auratus (F.) (Figure 7A)

Kentucky Counties: Ballard, Bath, Boyd, Bullitt, Christian, Clark, Fayette, Franklin, Grant, Grayson, Hardin, Hopkins, LaRue, Lawrence, Lewis, Logan, Nelson, Pendleton, Pulaski, Robertson, Rowan, Scott, Simpson, Warren, Wayne, Whitley
Years: 1892 (1), 1963 (1), 1967 (1), 1970 (1), 1971 (19), 1972 (1), 1983 (7), 1985 (5), 1987 (1), 1992 (1), 1993 (3), 1994 (1), 1995 (5), 2000 (1), 2002 (2), 2003 (4), 2004 (2), 2005 (32), 2006 (7), 2007 (3), 2008 (5), 2009 (2)
Months: May (3), June (57), July (37), August (7), September (1)
Abundance: 105 specimens: 6-BYUC, 12-CWC, 49-KYSU, 9-RJBC, 26-UKIC, 3-WKUC
Comments: Clark et al. (2004) reported this species associated with *Apocynum* (Apocynaceae).

Demotina modesta Baly (Figure 7B) (new state record)

Kentucky Counties: Ohio, Trigg
Years: 2007 (13), 2008 (3)
Months: May (13), June (3)
Abundance: 16 specimens: 13-BYUC, 3-KYSU
Comments: All specimens were found in two recent collection events. This species is an

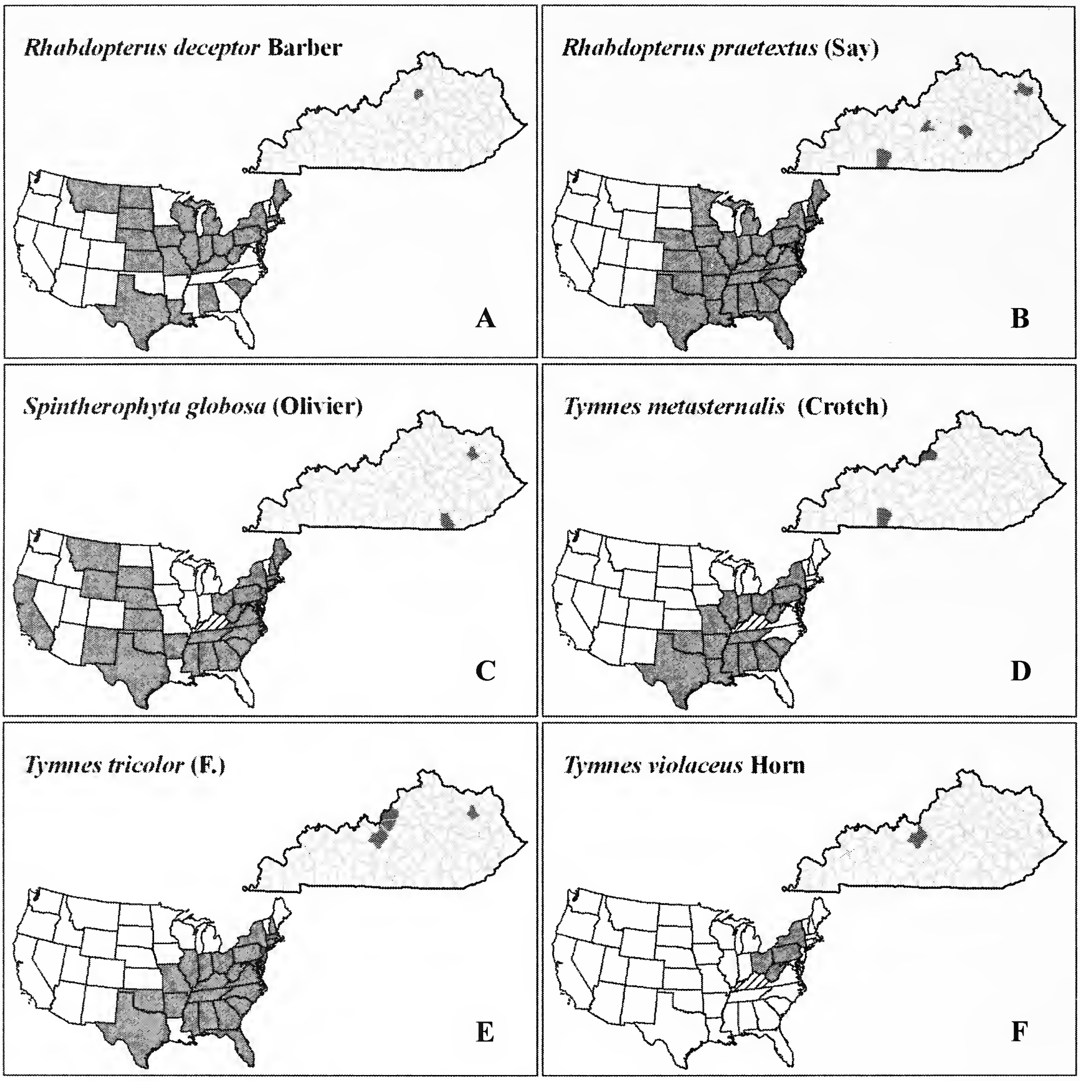

Figure 6. The known distribution of Eumolpinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

established immigrant to North America. Clark et al. (2004) reported this species associated with *Quercus* (Fagaceae).

Fidia confusa Strother (Figure 7C)

Kentucky Counties: unknown
Years: unknown
Months: unknown
Abundance: unknown
Comments: Strother and Staines (2008) referenced eight specimens from Kentucky with no further label data. Clark et al. (2004) reported this species associated with *Vitis* (Vitaceae).

Fidia longipes (F. E. Melsheimer) (Figure 7D) (new state record)

Kentucky Counties: Fayette, Pendleton, Pulaski, Russell
Years: 1971 (4), 1989 (1), 2005 (1)
Months: June (3), July (2), August (1)
Abundance: 6 specimens: 1-BYUC, 1-KYSU, 4-UKIC
Comments: Several specimens were collected via Malaise trap. Strother and Staines (2008) did not examine any Kentucky specimens but their distribution map showed the eastern *F. longipes* meeting the western *F. rileyorum* in the state.

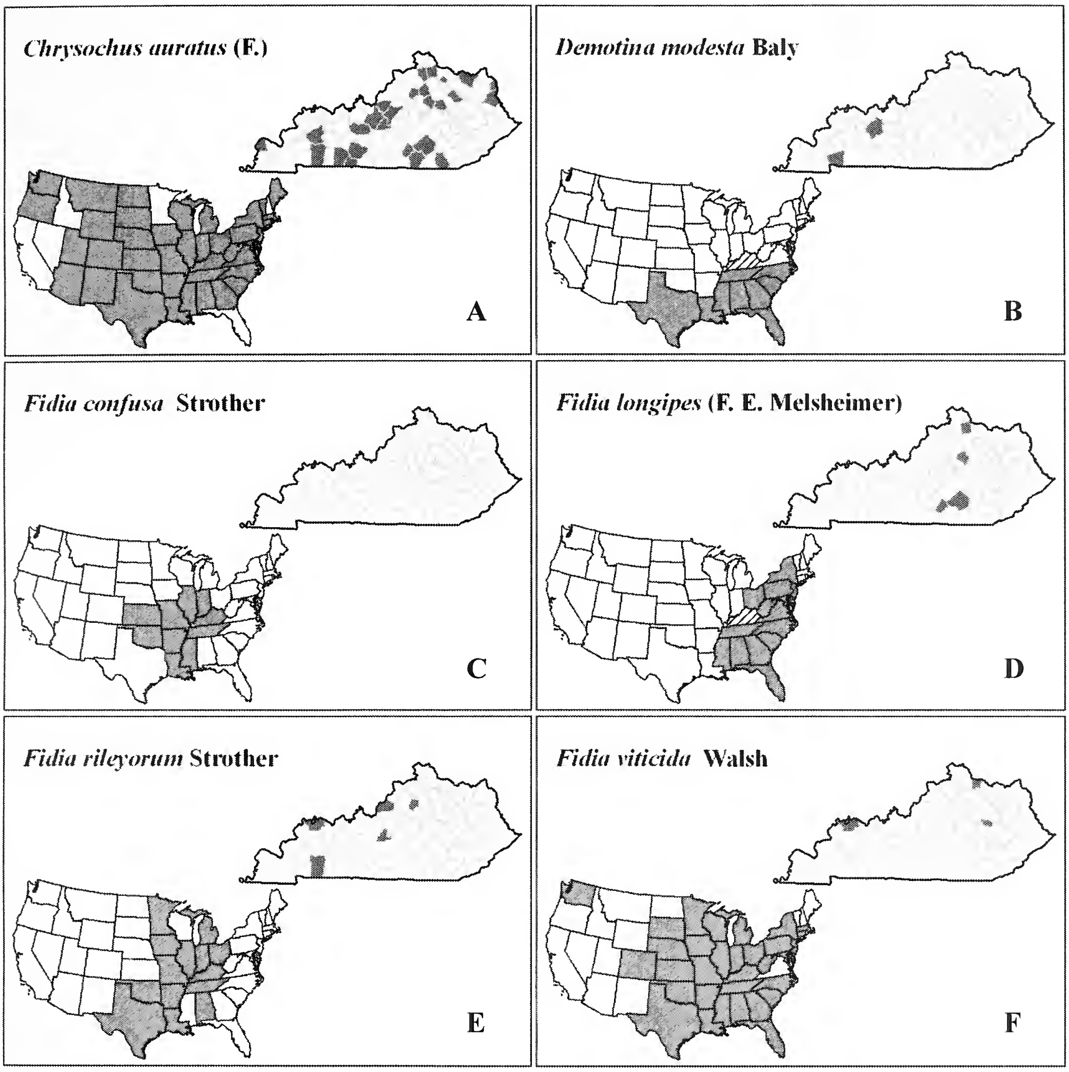

Figure 7. The known distribution of Eumolpinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Clark et al. (2004) reported this species associated with *Vitis* (Vitaceae).

Fidia rileyorum Strother (Figure 7E)

Kentucky Counties: Christian, Franklin, Henderson, Jefferson, LaRue
Year: 2006 (2)
Month: June (2)
Abundance: 2 specimens: 2-KYSU
Comments: Two specimens were collected at Thompson Creek Glades State Nature Preserve along the road. Strother and Staines (2008) reported this species from Christian, Franklin, Henderson and Jefferson Counties and the distribution map (Figure 7E) is based upon their data.

Fidia viticida Walsh (Figure 7F)

Kentucky Counties: Bracken, Henderson, Powell
Year: 1998 (2)
Month: July (2)
Abundance: 2 specimens: 2-BYUC
Comments: Two specimens were collected near the Ohio River. Strother and Staines (2008) reported this species from Henderson and Powell counties. Clark et al. (2004) reported this species associated with *Vitis* (Vitaceae).

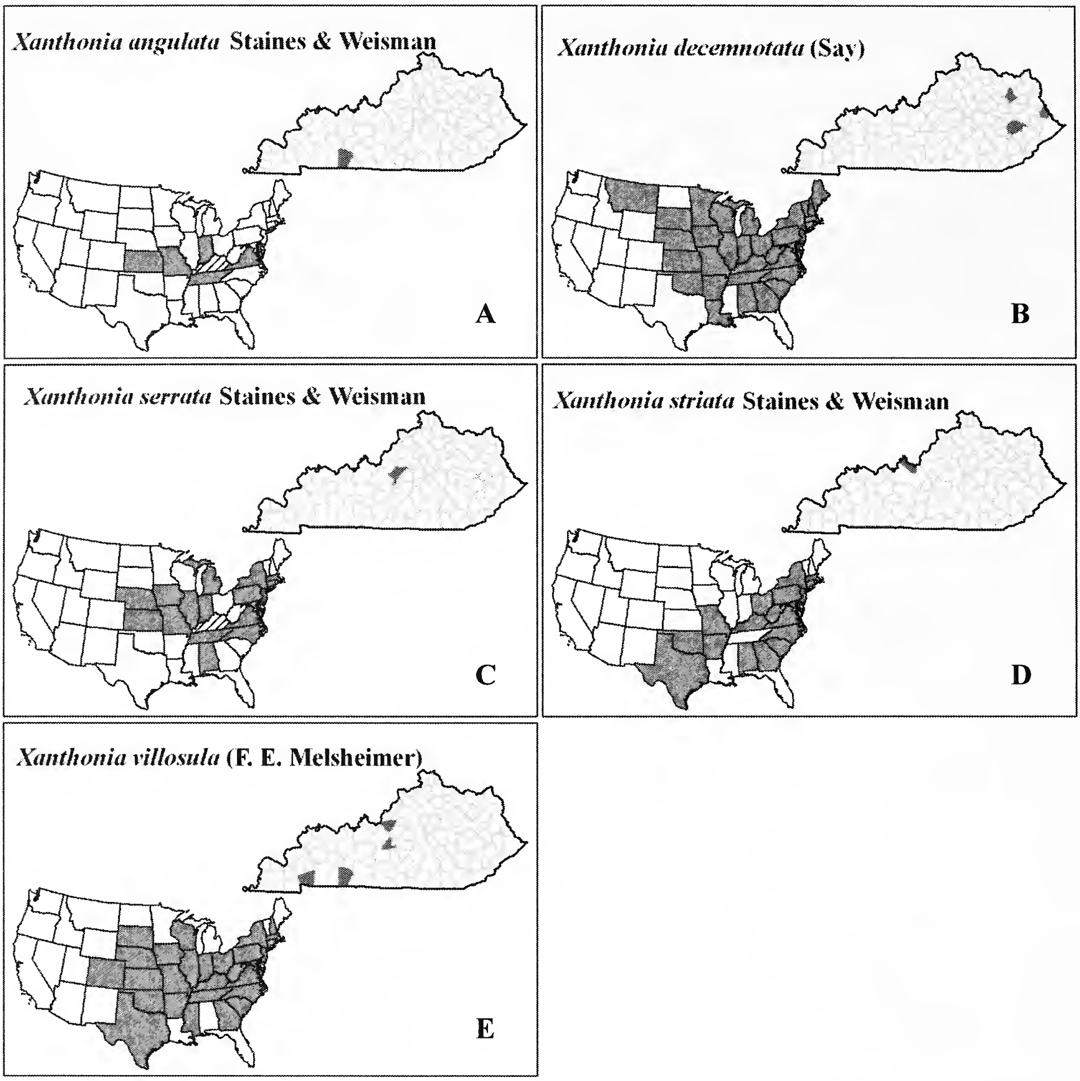

Figure 8. The known distribution of Eumolpinae (Coleoptera: Chrysomelidae) illustrated in grey shading for Kentucky counties and states of the United States. New state records reported herein are shown in cross-hatch.

Xanthonia angulata Staines & Weisman (Figure 8A) (new state record)

Kentucky County: Logan
Year: 2005 (1)
Month: May (1)
Abundance: 1 specimen: 1-KYSU
Comments: One specimen was collected at Raymond Athey State Nature Preserve. Clark et al. (2004) reported this species associated with *Quercus* (Fagaceae).

Xanthonia decemnotata (Say) (Figure 8B)

Kentucky Counties: Breathitt, Fulton, Martin, Rowan
Years: 1982 (1), 1994 (2), 2003 (1)
Months: April (1), May (2), June (1)
Abundance: 4 specimens: 2-BYUC, 1-CWC, 1-UKIC
Comments: Staines and Weisman (2001) reported this species from Fulton (Fulton County) based upon material in the United States National Museum.

Xanthonia serrata Staines & Weisman (Figure 8C) (new state record)

Kentucky County: Nelson
Year: 2009 (1)
Month: June (1)

Abundance: 1 specimen: 1-KYSU

Comments: One specimen was collected at Berheim Forest.

Xanthonia striata Staines & Weisman (Figure 8D)

Kentucky County: Meade

Year: unknown

Month: unknown

Abundance: unknown

Comments: Staines and Weisman (2001) reported this species from Fort Knox (Meade County). Clark et al. (2004) reported this species associated with *Quercus* (Fagaceae).

Xanthonia villosula (F. E. Meslheimer) (Figure 8E)

Kentucky Counties: Bullitt, LaRue, Logan, Trigg

Years: 1907 (4), 2006 (2), 2009 (1)

Months: June (5), July (2)

Abundance: 7 specimens: 4-CMC, 3-KYSU

Comments: Four specimens in the Dury collection are labeled "Ky. near Cin. O., June 21, 1907." Staines and Weisman (2001) reported this species from Cadiz (Trigg County; June 30, 1939) in the Snow Entomological Museum, University of Kansas, Lawrence.

DISCUSSION

We believe the data presented here are the most complete representation of eumolpine leaf beetles known from Kentucky. The large number of new state records documented here (20 of 46 species, or 43%) reflects a historical lack of leaf beetle collecting in Kentucky. Fourteen species (31% of total) were found as a result of the recent (2004–2009) extensive collecting effort, including ten of the new state records.

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Eastern Mistletoe (*Phoradendron leucarpum*, Viscaceae) Infestation of Host Trees in Jessamine County, Kentucky

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ABSTRACT

Eastern mistletoe [*Phoradendron leucarpum* (Raf.) Reveal & M.C. Johnston] was observed on 1104 host trees from 10 species and 8 families in Jessamine County, east-central Kentucky within the Inner Bluegrass and Hills of the Bluegrass Ecoregions. *Juglans nigra* was the major host tree (609 trees) followed by *Prunus serotina* (259 trees), *Ulmus americana* (116 trees), *Robinia pseudoacacia* (43 trees) and *Celtis occidentalis* (39 trees). The top three host species accounted for 89.1% of the infested trees. Eastern mistletoe exhibits an aggregated or clumped spatial distribution pattern among host trees characteristic of its life history and avian fruit and seed dispersal.

KEY WORDS: Eastern mistletoe, *Phoradendron leucarpum*, Viscaceae, host trees, Jessamine County, Kentucky

INTRODUCTION

Eastern mistletoe or American mistletoe [*Phoradendron leucarpum* (Raf.) Reveal & M.C. Johnston, Viscaceae] is an evergreen, epiphytic, dioecious hemiparasitic shrub of various deciduous woody taxa throughout the eastern United States. The distribution range of eastern mistletoe (hereafter, mistletoe) is Arkansas, Kentucky, Tennessee, northward from southeastern Missouri to southern Illinois, Indiana, Ohio, and West Virginia, eastward to southern Pennsylvania, New Jersey and Maryland, southward through the Atlantic coastal states, the Gulf Coastal States, and westward to eastern Texas and Oklahoma (Kuijt 2003).

We conducted an inventory of host trees infested with *Phoradendron leucarpum* in Jessamine County, located in east-central Kentucky within the Inner Bluegrass and Hills of the Bluegrass Regions (Figure 1). These two physiographic regions are characterized by soils developed over Ordovician limestone bedrock. Seven Kentucky mistletoe studies have been published (Reed and Reed 1951; Thompson 1992; Thompson and Noe, Jr. 2003; Thompson 2005; Thompson and Poindexter 2005; Thompson et al. 2008; Thompson and Rivers Thompson 2009). Our survey is an ongoing project to determine host tree specificity in selected ecoregions of Kentucky.

Braun (1943) reported that eastern mistletoe was especially abundant in the Bluegrass Region (Inner and Outer) and widely distributed throughout Kentucky on several tree species. Schneck (1884) found mistletoe to be common on black walnut (*Juglans nigra* L.) and black cherry (*Prunus serotina* Ehrh.) in the Kentucky Bluegrass Region. Garman (1913) noted that mistletoe was restricted mainly to black walnut in the Bluegrass Region and occurred less frequently on black locust (*Robinia pseudoacacia* L.), American elm (*Ulmus americana* L.), and other trees. Wharton and Barbour (1991) stated that mistletoe was present on several tree species in the Inner Bluegrass, with black walnut the most frequent, but it occurred occasionally on elms (*Ulmus* spp.) and common hackberry (*Celtis occidentalis* L.). Reed and Reed (1951) reported that mistletoe in the Bluegrass Region of Ordovician limestone hemiparasitic

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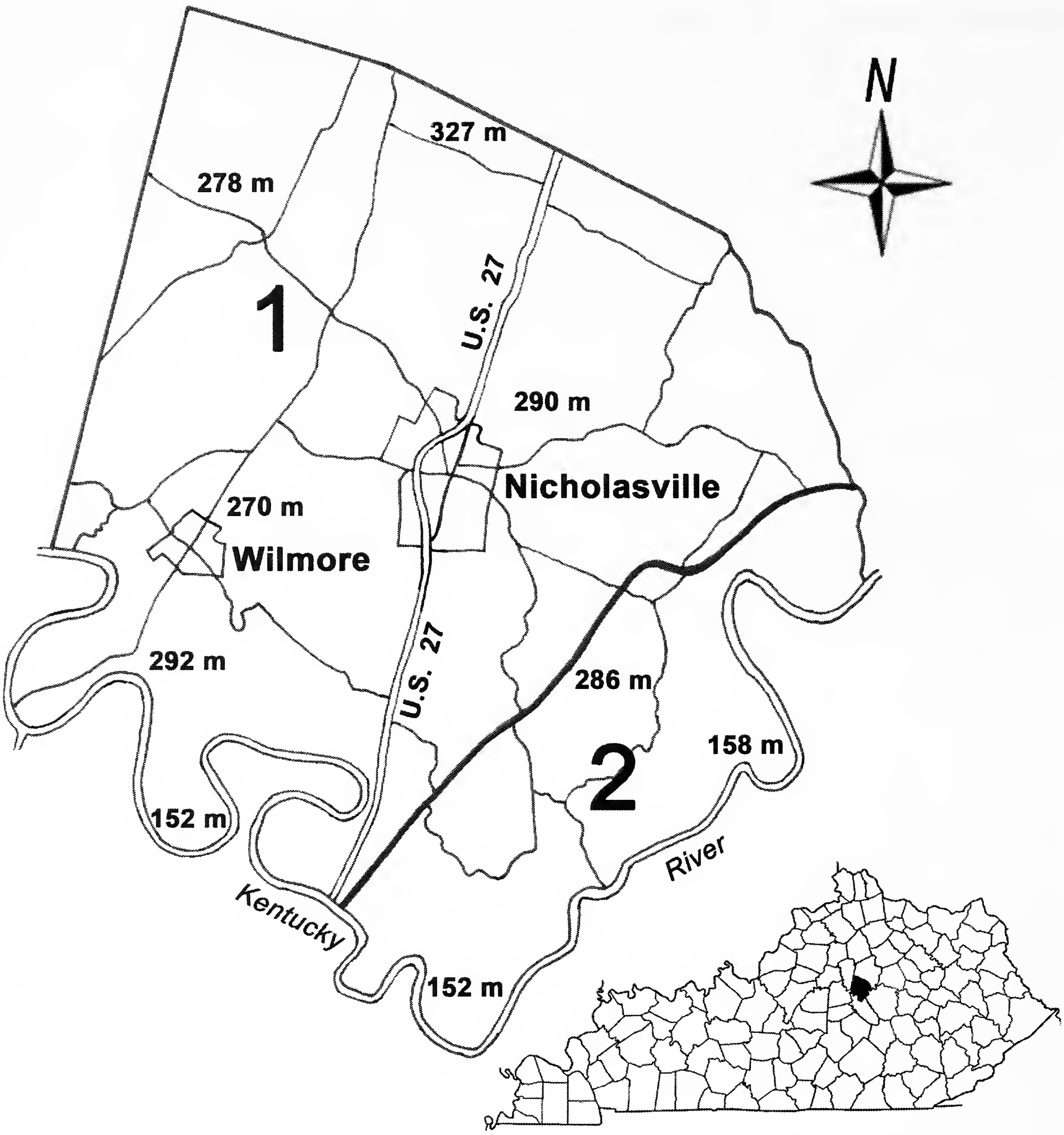

Figure 1. Jessamine County, Kentucky. (1) Inner Bluegrass and (2) Hills of the Bluegrass Ecoregions (Woods et al. 2002). Figure adapted from General Highway Map, Jessamine County (Kentucky Department of Transportation 1999).

on black walnut, elms, black locust, honey locust (*Gleditsia tricanthos* L.), common hackberry, maples (*Acer* spp.), Osage orange [*Maclura pomifera* (Raf.) Schneid.], white ash (*Fraxinus americana* L.), and black cherry in descending order of frequency. In Jessamine County, Reed and Reed (1951) collected mistletoe from *Prunus serotina* (*18665A US*), *Maclura pomifera* (*18665 US*), and *Juglans nigra* (*18666 US*) near High Bridge on limestone substrate. They also observed it on *Celtis occidentalis* in the vicinity but made no collections.

STUDY SITE OVERVIEW

Location

In east-central Kentucky, Jessamine County is contiguous to Fayette County to the north, Madison County to the east, Garrard County

to the south, Mercer County to the southwest, and Woodford County to the west. The Kentucky River delineates the eastern, southern, and southwestern boundaries of Jessamine County adjoining Madison, Garrard, and Mercer Counties The county is bisected by the north-trending four-lane highway, U.S. 27 (Figure 1). Jessamine County is comprised of an area of 458 km^2 (45,844 hectares) of land surface (McDonald et al. 1983). Nicholasville is the county seat and largest city with a population of over 27,000 people. The city lies almost directly in the middle of the county at latitude 37°52′58″ (37.882778) N and longitude 84°34′36″ (84.576667) W. Wilmore, the second largest city with a population of over 6000 people, is located in the western part of the county at 37°51′47″ (37.863056) N latitude and 84°39′28″ (84.657778) W longitude.

Physiography and Geology

Keys et al. (1995) classified east-central Kentucky into the Interior Low Plateau, Bluegrass Section, Inner Bluegrass Subsection of the Eastern Broadleaf Forest. Woods et al. (2002) subdivided Jessamine County into the Inner Bluegrass and Hills of the Bluegrass Ecoregions within the Interior Plateau Region based on geology, soils, topography, and vegetation (Figure 1). The Inner Bluegrass is underlain by Middle Ordovician limestone of the Lexington Formation and High Bridge Group above the Kentucky River Fault System. The Lexington Formation occurs throughout most of central, western, and northern Jessamine County. The High Bridge Group limestones form a narrow border or band along the Kentucky River, Jessamine Creek, Hickman Creek, and other smaller tributaries in the southwest part of the county. The Hills of the Bluegrass are composed of Upper Ordovician limestone and embedded calcareous shale and siltstones of the Garrard Siltstone and Clays Ferry Limestone Formations. The Hills of the Bluegrass borderline approximates the Kentucky River Fault Zone in the mid-eastern and southeastern portions of Jessamine County (Figure 1). Quaternary alluvium is found along Kentucky River, Jessamine Creek, Hickman Creek, Town Fork, Sinking Creek, Clear Creek East, and other small creeks (McDowell et al. 1981).

In Jessamine County, elevations at sea level range from 152 m at the Kentucky River below High Bridge at 292 m to 270 m at Wilmore, 290 m at Nicholasville and reach the highest point at 327 m near Brannon in the Inner Bluegrass. In the Hills of the Bluegrass, elevations range from 155 m at the Kentucky River to 274 m at Pink and peak around 286 m at Sulfur Well (Figure 1).

Soils

Major soil associations of Jessamine County are the Maury-McAfee, McAfee-Maury-Fairmont, Fairmont-Rock Outcrop, and the Eden-Culleoka Associations (McDonald et al. 1983). These four soil associations consist of well-drained, residual soils derived from predominantly limestone parent materials within both ecoregions. The Maury-McAfee Association is moderately deep to deep, alkaline to slightly acid loamy soils on level to undulating Inner Bluegrass uplands in the central and northern part of the Jessamine County. The McAfee-Maury-Fairmont Association is shallow to deep, alkaline to slightly acid loamy and clayey soils on rolling to hilly Inner Bluegrass uplands on the eastern and western part of the county. The Fairmont-Rock Outcrop Association is comprised of shallow, surficial, alkaline clayey soils and limestone outcrops on the precipices and cliffs of the Kentucky River Palisades. The Eden-Culleoka Association is moderately deep, neutral to acid droughty loamy and clayey soils on upland hilly ridges and steep valleys of the Hills of the Bluegrass in southeastern Jessamine County (McDonald et al. 1983).

Vegetation

Braun (1950) classified the vegetation of the Interior Low Plateau of Kentucky as belonging to the Western Mesophytic Forest Region, a transitional mosaic of mixed oak-hickory (*Quercus-Carya*) Forest and Mixed Mesophytic Forest. Küchler (1964) classified the potential natural vegetation of this part of Kentucky in the eastern deciduous forest region as *Quercus-Carya* forest. Upland communities in the two ecoregions of Jessamine County are represented by a scattered assortment of agricultural croplands, pastures, woodlands, forests, and developed land. The

Inner Bluegrass is mainly comprised of the oak-ash-red cedar (*Quercus-Fraxinus-Juniperus*) association on xeric rolling terrain and the oak-black locust-elm (*Quercus-Robinia-Ulmus*) association on more mesic undulating sites (Campbell 1987). The Hills of the Bluegrass are dominated by the *Quercus-Carya-Juniperus* association on xeric, hilly terrain and the oak-ash-elm (*Quercus-Fraxinus-Ulmus*) association or mixed hardwoods on mesic steep terrain (Woods et al. 2002).

Climate

The climate of Kentucky is humid mesothermal usually without water deficiency throughout the year and characterized by cool to cold winters and warm to hot summers (Trewartha and Horn 1980). Kentucky climatic data (1971–2000) are from the weather station at Dix River Dam, Mercer County, 7.3 km southwest of Jessamine County. Mean annual precipitation is 116.2 cm with October the lowest at 7.9 cm and May the highest at 12.4 cm. A mean annual snowfall of 14.2 cm occurs mainly in January. Mean annual temperature is 13.9°C with January the coldest month at 1.3°C and July the warmest month at 25.1°C. Mean length of the growing season is 203 days with the median first fall frost on 29 October, and the median last spring frost on 10 April (Kentucky Climate Center 2009).

METHODS AND MATERIALS

We conducted a survey of eastern mistletoe host trees within Jessamine County, Kentucky, from 9–13 February, and 14–16 March 2008, when tree leaves were not present. A Jessamine County General Highway Map was used for reference to all paved and unpaved county roads (Kentucky Department of Transportation 1999). Nikon Monarch™ binoculars (8 × 42 power) were used to spot visible signs of mistletoe infestation. Mistletoe-infested trees were identified, recorded by species, visible signs of mistletoe noted, and clumps/clusters counted. Representative mistletoe vouchers and accompanying host twigs were collected from host trees using a 12-m extendable fiberglass linesman pole with an attached hook. Specimens were dried, mounted, labeled, and deposited in the Berea College Herbarium (BEREA). Plant nomenclature followed Jones (2005).

Table 1. Host trees of *Phoradendron leucarpum* in Jessamine County, Kentucky.

Tree species	Number of host trees	Percentage of host trees
Juglans nigra L.	609	55.16
Prunus serotina Ehrh.	259	23.46
Ulmus americana L.	116	10.51
Robinia pseudoacacia L.	43	3.90
Celtis occidentalis L.	39	3.53
Gleditsia triacanthos L.	16	1.45
Fraxinus americana L.	10	0.91
Maclura pomifera (Raf.) Schneid	7	0.63
Acer saccharinum L.	3	0.27
Acer saccharum Marsh.	2	0.18
Total: 10	1104	100.00

RESULTS

Phoradendron leucarpum was observed on 1104 trees from 10 host tree species and 8 families within Jessamine County. The predominant host tree species were black walnut with 609 trees (55.16%) followed by black cherry with 259 trees (23.46%), American elm with 116 trees (10.51%), black locust with 43 trees (3.90%), and common hackberry with 39 trees (3.53%) (Table 1). The most abundant species accounted for 89.13% of the mistletoe-infested trees. Other trees in decreasing order of occurrence were honey locust (*Gleditsia triacanthos* L.), white ash, Osage orange, silver maple (*Acer saccharinum* L.), and sugar maple (*Acer saccharum* Marsh.) (Table 1). A majority of these calciphilous host taxa, 868 host trees, were found in the larger, open-canopy forested Inner Bluegrass Ecoregion and 236 host trees were recorded in the smaller area of the more closed-canopy forested Hills of the Bluegrass Ecoregion.

DISCUSSION

Black walnut, and black cherry were the two most important host trees in other eastern mistletoe surveys in east-central Kentucky (Thompson 1992; Thompson and Poindexter 2005; Thompson et al. 2008; Thompson and Rivers Thompson 2009). Schneck (1884) was accurate in his observations and assessment of mistletoe infesting mostly black walnut and black cherry in the Kentucky Bluegrass Region. Black cherry was not even noted as a host tree by Garman (1913), Braun (1943),

and Wharton and Barbour (1991), while Reed and Reed (1951) referred to it as an infrequent host tree in the Bluegrass Region. All 10 host tree species in Jessamine County were present in a contiguous Garrard County mistletoe survey (Thompson and Poindexter 2005). The order of occurrence in Jessamine County is the same as for Garrard County for the first four host trees: black walnut, black cherry, American elm, and black locust. Jessamine County had considerably fewer mistletoe-infested trees (1104) than two nearby east-central Kentucky counties. Adjacent Garrard County had 1740 mistletoe-infested trees (Thompson and Poindexter 2005) and Rockcastle County had 3502 trees infested with mistletoe (Thompson and Noe, Jr. 2003). Fewer mistletoe-infested trees in Jessamine County may be partly correlated with it being a considerably smaller county for host tree presence and with a larger proportion agricultural cropland and urban residential, commercial and industrial-developed land. Jessamine County is also comprised of two ecoregions, the Inner Bluegrass and the Hills of the Bluegrass. Garrard County lies primarily in the Ordovician Inner Bluegrass and Hills of the Bluegrass Ecoregions with Ordovician Outer Bluegrass and a small portion of Devonian-Mississippian Knobs-Norman Uplands. Both Jessamine and Garrard Counties are characterized by Ordovician limestone geology, calcareous soils, forest vegetation of calciphilous hardwood and red cedar stands, and similar topographic-moisture relief and physiographic terrain.

The major portion of Jessamine County is open, undulating Inner Bluegrass with mainly upland open-canopied forest, while the eastern Hills of the Bluegrass are largely composed of steeper, hilly topography occupied by both lowland and upland closed-canopied forest. Mistletoe-infested trees tend to be solitary or scattered calciphilous species of pastures, fields, woodlots, groves, fencerows, and forest edges throughout the level, rolling, and hilly topography. The availability of tall, mature open-canopied trees in upland terrain, rather than lowland forest terrain or closed-canopy upland forests, is an important factor in mistletoe infestation (Thompson and Noe, Jr. 2003; Thompson and Poindexter 2005; Thompson and Rivers Thompson 2009).

The small and older unincorporated towns, e.g., Bethel, Black Bridge, Brannon, Camp Nelson, Dixon Town, High Bridge, Keene, Sulfur Well, Union Mills, and Vineyard, had more mistletoe-infested trees than the faster-growing, urban-developed cities of Nicholasville and Wilmore. This observation is in contrast with other eastern mistletoe studies in east-central Kentucky that showed larger urban towns or cities with an overall greater mistletoe infestation (Thompson and Noe, Jr. 2003; Thompson and Poindexter 2005; Thompson et al. 2008). The greater distribution of mistletoe in unincorporated towns could be partly because these towns have taller, older open-crowned trees in close proximity to each other which are preferred sites for birds to perch, feed, and roost.

Eastern mistletoe exhibits an aggregated spatial distribution pattern among its host trees. This clumped spatial pattern is a function of mistletoe dioecious life history, avian dispersal of viscous mistletoe seeds, subsequent seed germination and establishment in suitable host trees, and the distribution and availability of host trees for infestation (Panvini and Eickmeier 1993; Thompson and Noe, Jr. 2003; Thompson and Rivers Thompson 2009).

It is well documented that eastern mistletoe has a considerable host tree specificity in certain geographical regions over others. In addition, the same tree species over a large geological or physiographic region may have infestation in one area and non-infestation in another area. Infestation or non-infestation of trees has been connected to physiography, geological substrates, soils, existing vegetation, and host tree availability (Panvini 1991; Panvini and Eickmeier 1993; Reed and Reed 1951; Thompson and Noe, Jr. 2003). All abiotic and biotic factors in conjunction with climate over time determine the vegetation for any given geographical region. Moreover, throughout the Kentucky counties of the Inner Low Plateau, the Oak-Hickory Forest Region is comprised of certain calciphilous hardwood trees that are more susceptible to mistletoe-infestation than others.

Mistletoe infestation of certain host trees and not others when host trees are readily present in a geographical region must be highly correlated to the genetics of eastern

mistletoe, i.e., the presence of mistletoe host races. Drés and Mallet (2002) defined host races as "genetically differentiated sympatric populations of parasites that use different hosts, and between which there is appreciable gene flow." Panvini (1991) found genetic variation from allozyme studies as evidence for host races within and among populations of *Phoradendron leucarpum*. Ample evidence for host races in species of the Viscaceae is supported from numerous studies; e.g., a molecular genetic study of the European mistletoe (*Viscum album* L.) has provided reliable evidence for three host races (subspecies) for host specificity (Zuber and Widmer 2000). Further molecular genetic studies of *Phoradendron leucarpum* are needed to further elucidate genetic relationships between host races and host specificity.

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An Evaluation of the Fishes of Obion Creek with the Kentucky Index of Biotic Integrity

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ABSTRACT

Nineteen locations were sampled in the Obion Creek drainage from July 2007 until May 2008 to determine species composition of fishes in the channelized drainage in western Kentucky and evaluate anthropogenic disturbances with the Kentucky Index of Biotic Integrity. The Kentucky Index of Biotic Integrity (KIBI) was used to evaluate 17 of the 19 locations. Survey results of the Obion Creek drainage lists18 families represented by 65 species. The Obion Creek drainage is in the Jackson Purchase area of western Kentucky; an area where a majority of the land is in heavy agricultural use.

Five species collected were considered rare by the Kentucky State Nature Preserves Commission: blacktail shiner (*Cyprinella venusta*), taillight shiner (*Notropis maculatus*), lake chubsucker (*Erimyzon succeta*), chain pickerel (*Esox niger*), and central mudminnow (*Umbra limi*). Three species collected were considered exotic and highly invasive: grass carp (*Ctenopharyngodon idella*), silver carp (*Hypophthalmichthys molitrix*), and the common carp (*Cyprinus carpio*). Species richness has increased over previous collections in a 40 year period. Kentucky Index of Biotic Integrity scores ranged from fair to poor in the Obion Creek drainage.

KEY WORDS: Obion Creek, channelized, Kentucky Index of Biotic Integrity, Jackson Purchase area

INTRODUCTION

The Jackson Purchase area is a unique and definable area in Kentucky and is the only portion of the state that is in the Gulf Coastal Plain (Webb 1974). There are four major streams draining the Purchase region: Obion Creek, Bayou de Chien, Clarks River, and Mayfield Creek. All four streams have experienced major hydromodification and habitat change throughout the 20th century (Table 1). Obion Creek originates in Graves County and flows approximately 67 km (42 mi) westward to its confluence with the Mississippi River near Hickman, Kentucky (Smith 1968). The Obion Creek watershed is in agricultural area and comprises an area of 83,409 ha (206,108 ac) in the following counties: Graves, Hickman, Carlisle, and Fulton (Smith 1968). Murphy's Pond lies in the Obion Creek floodplain and is a natural cypress swamp that is located adjacent to the mainstem of Obion Creek in the northeast corner of Hickman County and may have a species composition similar to when it was formed (Timmons 1988). Obion Creek is spring-fed and is a low gradient, fifth order stream presently with few riffles (McMurray 2004). The stream characteristics found by Smith in 1968 were an alternating series of deep, sluggish pools and swift, well defined riffles. The majority of the stream substrates are comprised of clay-like mud situated beneath sand, gravel, and woody debris (McMurray 2004).

Natural streams meander and have pool-riffles patterns (Orth and White 1999). Channelization destroys natural stream habitat by straightening the channel and reducing the length of the stream. Continual sedimentation may cause gradual depletion of fish habitat (Larsen 1999). Channelization can have devastating effects on resident fish fauna and can reduce numbers and biomass of sport fishes by 90% in warm water streams (Rabeni and Jacobson 1999). It is potentially the most comprehensively destructive activity that humans can impose on a stream (Hubbard et al. 1993).

Paul L. Smith (1968) was the first to thoroughly sample the fishes of Obion Creek. His survey was conducted in 1968 prior to several major flood and silt control measures and resulted in 54 species. He used gill nets, rotenone, and three different types of seines. Previously, the only published data on Obion Creek was that of Albert J. Woolman, who collected fishes in the summer of 1890. He sampled for two days and collected thirty species near Cypress in Hickman County, Kentucky, an area near the present-day

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Table 1. History of hydromodification events in the Obion Creek drainage (Rundle and Spencer 1997).

Date	Event
1916	10 mile stretch of Obion Creek in upper drainage cleared.
1924	First attempt at channelization of Obion, Mayfield, and Bayou de Chien unsuccessful.
1920s	Obion Creek and Bayou de Chien channelization began by using a floating dredge.
1927	First reaches of Mayfield Creek channelized.
1937	Channelization completed at Mayfield Creek.
1940s	Kentucky Highway 307 built.
1965	Congress authorizes Obion Creek flood control improvement project in the Flood Control Act of 1965.
1960s	Soil Conservation Service channelized Little Creek.
1980	Obion Creek cleared out from Pryorsburg to a very short distance west of Kentucky highway 307.
1990	Obion Creek cleared out from Kentucky Highway 307 for a distance past the powerline that runs adjacent to Kentucky Highway 307 to the east.

Wallace Tract of the Obion Creek Wildlife Management Area. Woolman (1890) described the stream as narrow and deep. The bottom was characterized as mud that was 61 cm to 122 cm (2 to 4 ft) deep, lying on a stratum of "quicksand" making fish collections difficult (Woolman 1890). Timmons (1988) collected 31 species during 1984–1986 in Murphy's Pond and Obion Creek adjacent to the cypress swamp. The most recent sampling efforts on Obion Creek occurred in the summer of 1987 by the Kentucky Department of Fish & Wildlife Resources. Thirty-six species were collected at 11 sites (McLemore and Mattucks 1988). Backpack electrofishers and boat electrofishers were used. Also, the toxicant rotenone was used in their sampling efforts.

My objectives were to compare fish species composition and distributions in Obion Creek after 40 years of modification since Smith's study (1968) and to evaluate each site with the Kentucky Index of Biotic Integrity (KIBI). The Kentucky Index is an adaptation of the original Index of Biotic Integrity created by Karr (1981).

MATERIALS AND METHODS

Twelve of Smith's 1968 collection sites were selected in the Obion Creek drainage, and additional sampling locations were based on accessibility using regional USGS 1:24,000 scale maps. Sites were sampled in late summer and early fall 2007 and spring 2008 using a Smith-Root Inc. LR-24 (24 volt) backpack electrofishing unit and 3.4 × 1.8 m seines. The mouth of Obion Creek was sampled with an electrofishing boat provided and operated by the Kentucky Department of Fish and Wildlife Resources. Because 17 of the 19 locations were scored with the Kentucky Index of Biotic Integrity (KIBI-see below), sites sampled with backpack electrofishing unit were shocked for 600–1800 sec and seines were used for 30–60 min for standardized techniques (Kentucky Division of Water 2002).

GPS coordinates were determined for each site and the Mid-America Remote Sensing Center (MARC) at Murray State University mapped the sampling sites for the drainage. All fish collected were preserved in 10% buffered formalin in the field and later stored in 45% isopropyl alcohol and placed in the fish collection in the Biology Building, Murray State University. Fish were identified using Etnier and Starnes (1993). Collections were used in determining KIBI scores that assesses stream health by analyzing fish communities at each site. Kentucky Index of Biotic Integrity uses seven metrics: native species richness; darter, madtom, and sculpin richness; intolerant species richness; simple lithophilic spawning species richness; relative abundance of insectivorous individuals; relative abundance of tolerant individuals; and relative abundance of facultative headwater individuals (Compton et al. 2003). Values for each site were obtained from an Excel 2003 KIBI template that simplified the calculation process.

RESULTS

Survey results (Table 2) of the Obion Creek drainage lists 18 families represented by 65 species. Five species collected are considered rare by the Kentucky State Nature Preserves Commission (2000). The rare species are the blacktail shiner (*Cyprinella venusta*), a species of special concern because it exists in a limited geographic area; taillight shiner (*Notropis maculatus*), a species considered threatened; central mudminnow (*Umbra limi*), a species considered threatened; lake chubsucker (*Erimyzon sucetta*), also a species considered threatened, and the chain pickerel (*Esox niger*), a species of special concern that should

Table 2. Fishes of the Obion Creek drainage.

Species	Sites
Amiidae	
Amia calva Linnaeus	10, 17
Lepisostidae	
Lepisosteus oculatus Winchell	17
Lepisosteus platostomus Rafinesque	17
Polyodontidae	
Polyodon spathula (Walbaum)	17
Esocidae	
Esox americanus Gmelin	6
Esox niger Lesueur	19
Clupeidae	
Alosa chrysochloris (Rafinesque)	17
Dorosoma cepedianum (Lesueur)	17
Dorosoma petenense (Guenther)	17
Cyprinidae	
Ctenopharyngodon idella (Valenciennes)	17
Cyprinella lutrensis (Baird & Girard)	1, 2, 3, 7, 10, 12, 13, 19
Cyprinella venusta Girard	7, 10, 14, 15
Cyprinus carpio Linnaeus	17
Hybognathus nuchalis Agassiz	10, 11
Hypophthalmichthys molitrix (Valenciennes)	17
Lythrurus fumeus (Evermann)	3, 4, 6, 8, 11, 14, 15, 19
Lythrurus umbratilis (Girard)	1, 2, 3, 5, 6, 8, 12, 14, 18, 19
Notemigonus crysoleucas (Mitchill)	1, 2, 3, 4, 6, 8, 10, 12, 13, 15, 16, 18, 19
Notropis atherinoides Rafinesque	17
Notropis buchanani Meek	17
Notropis maculatus (Hay)	4
Phenacobius mirabilis (Girard)	1, 2, 6, 7, 15, 19
Pimephales promelas Rafinesque	11
Pimephales vigilax (Baird & Girard)	3, 4, 5, 7, 10, 14, 15
Semotilus atromaculatus (Mitchill)	1, 2, 3, 6, 8, 9, 11, 12, 13, 16, 18, 19
Catostomidae	
Carpoides carpio (Rafinesque)	17
Catostomus commersonii (Lacepede)	6
Erimyzon oblongus (Mitchill)	1, 2, 3, 6, 9, 10, 11, 12, 13, 15, 18, 19
Erimyzon succeta (Lacepede)	18
Ictiobus bubalus (Rafinesque)	17
Minytrema melanops (Rafinesque)	2, 3, 7
Atherinopsidae	
Labidesthes sicculus (Cope)	4
Ictaluridae	
Ameiurus melas (Rafinesque)	8, 16, 18
Ameiurus natalis (Lesueur)	1, 2, 3, 6, 7, 11, 15, 18, 19
Ictalurus punctatus (Rafinesque)	7, 10, 17
Noturus miurus Jordan	7, 14
Noturus gyrinus (Mitchill)	4, 6, 10, 18
Noturus nocturnus Jordan & Gilbert	7, 10, 14, 15
Pylodictus olivaris (Rafinesque)	7, 17
Fundulidae	
Fundulus olivaceous (Storer)	all sites except 17
Fundulus notatus (Rafinesque)	18
Poeciliidae	
Gambusia affinis (Baird & Girard)	1, 2, 3, 4, 8, 9, 10, 11, 12, 18, 19

Table 2. Continued.

Species	Sites
Aphredoderidae	
Aphredoderus sayanus (Gilliams)	1, 2, 4, 6, 7, 11, 15, 16, 18, 19
Moronidae	
Morone chrysops (Rafinesque)	17
Morone mississippiensis Jordan & Eigenmann	17
Centrarchidae	
Centrarchus macropterus (Lacepede)	4, 16, 19
Lepomis cyanellus Rafinesque	1, 2, 3, 4, 6, 7, 9, 10, 11, 12, 14, 15, 16, 18, 19
Lepomis gulosus (Cuvier)	3, 6, 15, 16, 18, 19
Lepomis humilis (Girard)	5
Lepomis macrochirus Rafinesque	1, 2, 3, 4, 5, 6, 7, 11, 15, 16, 18, 19
Lepomis megalotis (Rafinesque)	2, 3, 4, 5, 7, 10, 14, 15, 16, 18, 19
Lepomis symmetricus Forbes	10
Micropterus punctulatus (Rafinesque)	3, 7, 10, 15
Micropterus salmoides (Lacepede)	4, 10, 18
Pomoxis annularis Rafinesque	4, 5, 17, 19
Pomoxis nigromaculatus (Lesueur)	4
Elassomatidae	
Elassoma zonatum Jordan	6
Umbridae	
Umbra limi (Kirtland)	11
Percidae	
Etheostoma asprigene (Forbes)	7, 10
Etheostoma chlorosomum (Hay)	2, 4, 6, 10, 19
Etheostoma gracile (Girard)	7, 8, 10, 14, 18
Etheostoma histrio Jordan & Gilbert	10, 14
Percina sciera (Swain)	6, 7, 14, 15
Percina vigil (Hay)	6, 7, 14, 15
Sciaenidae	
Aplodinotus grunniens Rafinesque	17

be monitored (Kentucky Nature Preserves Commission 2000).

A total of 19 locations (Figure 1) was sampled. Nine of the sites were in the mainstem of Obion Creek. The other locations were at tributaries of Obion Creek. The tributaries are Bowles Creek, Brush Creek, Cane Creek, Guess Creek, Hopewell Creek, Little Creek, and Little Cypress Creek.

Kentucky Index of Biotic Integrity (KIBI) scores (Table 3) for the Obion Creek drainage sites ranged from poor, to fair. Most sites scored poor. All sites used the KIBI Mississippi Valley-Interior River (MVIR) Ichthyoregion criteria (Table 4).

DISCUSSION

Sixty-five species from 18 families were found in the Obion Creek drainage compared to 40 years ago when only 54 species from 17 families were found in the Obion Creek drainage. The fishes not found by Smith's (1968) study include 19 species: spotted gar (*Lepisosteus oculatus*), paddlefish (*Polyodon spathula*), skipjack herring (*Alosa chrysochloris*), threadfin shad (*Dorosoma petenense*), white sucker (*Catostomus commersonii*), lake chubsucker (*Erimyzon succeta*), grass carp (*Ctenopharyngodon idella*), blacktail shiner (*Cyprinella venusta*), silver carp (*Hypophthalmichthys molitrix*), ribbon shiner (*Lythrurus fumeus*), ghost shiner (*Notropis buchanani*), taillight shiner (*Notropis maculatus*), bullhead minnow (*Pimephales vigilax*), brook silverside (*Labidesthes sicculus*), freckled madtom (*Noturus nocturnus*), yellow bass (*Morone mississippiensis*), spotted bass (*Micropterus punctulatus*), chain pickerel (*Esox niger*), and central mudminnow (*Umbra limi*).

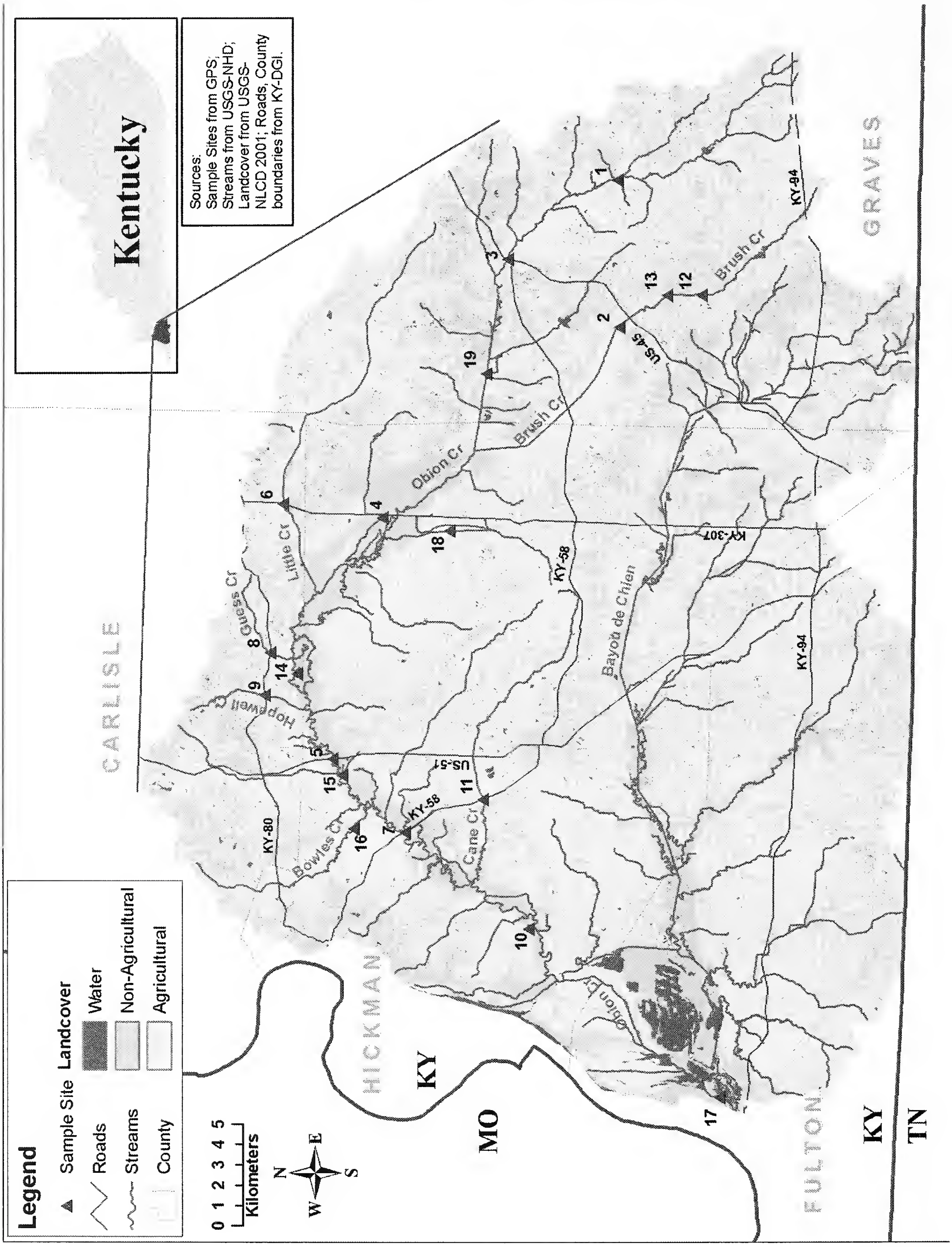

Figure 1. Sampled locations in the Obion Creek drainage.

Eight species found in Smith's (1968) collection were not collected in my efforts: goldeye (*Hiodon alosoides*), bigmouth buffalo (*Ictiobus cyprinellus*), golden redhorse (*Moxostoma erythrurum*), shorthead redhorse (*Moxostoma macrolepidotum*), cypress minnow (*Hybognathus hayi*), steelcolor shiner (*Notropis whipplei*), pugnose minnow (*Opso-

Table 3. Collection sites in the Obion Creek drainage with KIBI scores.

Locality	Species richness	KIBI
Site 1. Obion Creek 36 38.206N 088 40.898W	12	23.9 poor
Site 2. Brush Creek 36 38.083N 088 45.742W	15	20.4 poor
Site 3. Obion Creek 36 41.084N 088 43.591W	16	26.9 poor
Site 4. Obion Creek 36 44.296N 088 52.102W	17	15.8 poor
Site 5. Obion Creek N/A	07	N/A
Site 6. Little Creek 36 46.951N 088 51.813W	12	34.4, 35.1 fair
Site 7. Obion Creek 36 43.519N 089 02.595W	20	34.3 fair
Site 8. Guess Creek 36 47.201N 088 56.742W	09	38.0 fair
Site 9. Hopewell Creek 36 47.317N 088 58.150W	05	33.4 fair
Site 10. Obion Creek 36 40.183N 089 05.682W	22	31.4 poor
Site 11. Cane Creek 36 41.469N 089 01.445W	12	17.9 poor
Site 12. Brush Creek 36 35.919N 088 44.637W	08	40.5 fair
Site 13. Brush Creek 36 36.820N 088 44.663W	05	33.0 fair
Site 14. Obion Creek 36 46.489N 088 57.419W	13	35.3 fair
Site 15. Obion Creek 36 45.225N 088 00.737W	17	24.3 poor
Site 16. Bowles Creek 36 44.889N 089 02.503W	10	25.7 poor
Site 17. Obion Creek 36 34.995N 089 11.107W	19	N/A
Site 18. Little Cypress Creek 36 42.496N 088 52.605W	18	39.3 fair
Site 19. Obion Creek 36 41.606N 088 47.383W	19	22.6 poor

poeodus emiliae), and American eel (*Anguilla rostrata*).

Very common species found in both surveys include; creek chubsucker (*Erimyzon oblongus*), golden shiner (*Notemigonus crysoleucas*), creek chub (*Semotilus atromaculatus*), yellow bullhead (*Ameiurus natalis*), blackspotted topminnow (*Fundulus olivaceous*), western mosquitofish (*Gambusia affinis*), pirate perch (*Aphredoderus sayanus*), green sunfish (*Lepomis cyanellus*), and bluegill (*Lepomis macrochirus*). The most widespread fish in Smith's (1968) survey was the green sunfish that is also common in my results. The most widespread fish in my survey was blackspotted topminnow that was found at every site except site 17. All of these fish are considered tolerant according to the KIBI except the blackspotted topminnow, creek chubsucker, and pirate perch.

All but 5 species of fishes collected by the Kentucky Department of Fish & Wildlife Resources (KDFWR) in 1987 were collected in my survey with the exception of 5 species. The species not collected were the bluntface shiner (*Notropis camurus*), longnose gar (*Lepisosteus oculatus*), largemouth buffalo (*Ictiobus cyprinellus*), rainbow darter (*Etheostoma caeruleum*), and goldeye (*Hiodon alosoides*). The bluntface shiner is considered rare and sporadic in Obion Creek (Burr and Warren 1986). The KDFWR collected one rainbow darter; however this species does not occur west of the Land between the Lakes region, and therefore this individual may be a misidentified mud darter.

Table 4. KIBI Ichthyoregion criteria for Mississippi Valley-Interior River (MVIR).

Classification	Score
Excellent	≥67
Good	48–66
Fair	32–47
Poor	16–31
Very Poor	0–15

All of the species Smith collected at Murphy's pond were in my collection except the bigmouth buffalo. The collection by Timmons (1988) was more comprehensive and complete at Murphy's Pond. The species he collected that I did not include bigmouth buffalo, black buffalo (*Ictiobus niger*), brown bullhead (*Ictalurus nebulosus*), and dollar sunfish (*Lepomis marginatus*). Branson (1972) collected the northern starhead topminnow (*Fundulus dispar*) near Murphy's Pond in a channel that drained into the cypress swamp. The northern starhead topminnow was not collected in my survey, and Branson's record was the only collection of the northern starhead other than from Reelfoot Lake drainage in Kentucky.

Smith (1968) suggested that the harlequin darter (*Etheostoma histrio*) and mud darter (*Etheostoma asprigene*) may be eliminated from the Obion Creek drainage due to hydromodification and habitat change, but both species still persist in the drainage. However,

Smith (1968) was correct when he predicted that the species composition of the Obion Creek drainage would change, although he was unable to predict to what extent. Smith suggested a survey be done 4–5 years after his project. Unfortunately, changes have not been documented until recently.

Possibly, fishes that were collected by Smith (1968) that were not collected in my study could be due to sampling techniques. Smith (1968) used rotenone which is a highly effective toxicant that is not commonly used today. Rotenone is very toxic to fish; a 1.0-mg/L concentration of 5% rotenone solution usually kills all fishes with exception of the most resistant species of fish such as gars, bullheads, and bowfin (Bettoli and Macenia 1996). Deeper water sampling in the lower Obion Creek may have yielded some additional species such as the American eel, goldeye, pugnose minnow, and bigmouth buffalo. I only sampled once near the Mississippi River. It is doubtful that the golden redhorse and shorthead redhorse occur in the Obion Creek drainage because, according to Burr and Warren (1986), the only record was from Smith (1968), and it is unsubstantiated. Finding the steelcolor shiner would have been unlikely because only one site has produced this species in the Obion Creek (Burr and Warren 1986). Burr and Warren (1986) mention that the steelcolor shiner is sporadic and rare in extreme western Kentucky. The eight species that only Smith (1968) collected were uncommon in his survey and localized, with the exception of the bigmouth buffalo, and it was common in his survey. It is doubtful that poor land use has led to not finding these species except potentially for the cypress minnow.

Eight of the nineteen new species found in my survey could be due to the use of an electrofishing boat near the mouth of Obion Creek into the Mississippi River. The eight species found near the Mississippi River are associated with large rivers: spotted gar, paddlefish, skipjack herring, threadfin shad, grass carp, silver carp, ghost shiner, and yellow bass (Etnier and Starnes 1993). The remaining eleven species not found by Smith (1968) were found throughout the drainage: white sucker, lake chubsucker, blacktail shiner, ribbon shiner, taillight shiner, bullhead minnow, brook silverside, freckled madtom, spotted bass, chain pickerel, and central mudminnow. With the exception of the two additional exotic species, the increased species richness could be a sign of an improving watershed with some improved agricultural practices, but Obion Creek is still imperiled as shown by the low KIBI scores. Several sites in my study area had clear water and were surrounded by hardwoods. Characteristics such as these were mentioned by Woolman (1890) before major habitat changes occurred. It is impossible to compare habitats with Smith's (1968) findings because he did not describe habitats in his paper.

Site 4 in my survey was the area modified in the channelized portion of Obion Creek to recreate meanders. Site 4 is directly off of Highway 307 in the Wallace tract of the Obion Creek Wildlife Management Area. This site is presumably near Woolman's collection site in the late 19th century. One of the species he collected there that Smith did not was present in my collection, the brook silverside. Although site 4 was very turbid and had a poor KIBI score, this modification could have led to this finding.

Three exotic species were collected; the silver carp, common carp, and the grass carp. Common carp were introduced to North America in the 1800s and were found in Smith's (1968) study. Silver carp were first introduced into the United States in the 1970s for research projects and were also stocked into wastewater lagoons and fish culture ponds in several states (Kolar et al. 2005). After the silver carp escaped confinement during flooding they have become well established and highly invasive with reproducing populations in a majority of the Mississippi river basin (Kolar et al. 2005.) Because silver carp feed by filtering phytoplankton and zooplankton, silver carp compete directly with paddlefish, a North-American native filter-feeding fish and other species that target zooplankton (Chapman 2003). Recently, silver carp have gained attention by literally impacting boaters because silver carp react to the sound of boat engines by jumping out of the water and have the potential to strike and injure boaters (Chapman 2003). Grass carp were first suggested by Swingle (1957) for stocking in the United States for weed control. Later the grass carp was introduced into the country from Malaysia in 1963 in Arkansas and Alabama (Guillory and

Gasaway 1978). Since 1963 grass carp have spread along the main channel of the Mississippi River and into its various tributaries in the South and Midwest. Grass carp have direct effects on plant communities which then disrupt other organisms such as invertebrates, fishes, and waterfowl that feed and live within target plants consumed by the grass carp (Bain 1993).

In addition to examining the species composition and distribution of the fishes of the Obion Creek drainage, I evaluated most of the sampled sites with the Kentucky Index of Biotic Integrity (KIBI). The multimetric index determines the health of a stream by examining the fish communities present. It was designed to show changes in the environment due to anthropogenic disturbances (Compton et al. 2003). The sites sampled and evaluated with the KIBI ranged from fair to poor (Figure 2). Most poor sites were in the mainstem of Obion Creek. According to Karr (1981) sites classified as poor suggest that the site is dominated by omnivores, pollution-tolerant species, and habitat generalists; also there are few top carnivores. Hybrids and diseased fish may be present that are negatively scored. The classification of fair suggests signs of deterioration that include fewer intolerant species and a more skewed trophic structure (Karr 1981). Unfortunately, I cannot make comparisons between my survey and Smith's (1968) based on the KIBI because Smith did not report the number of individuals with the species. Also, he did not report habitat conditions per site. I can only speculate that if the KIBI was in existence 40 years ago, Smith's (1968) findings perhaps would have been poor because the species richness was much less 40 years ago.

Finally, due to similarities and closeness of the Obion Creek drainage to that of the Bayou de Chien drainage there was concern that the relict darter (*Etheostoma chienense*) may possibly be found in the upper sites of the survey. The relict darter is an endangered species considered endemic to the Bayou de Chien drainage of Graves and Hickman County in western Kentucky (USFWS 1995). Population estimates for the entire Bayou de Chien drainage range from 9,533 to 31,293 individuals (Piller and Burr 1998). However, the relict darter was not collected in my survey nor has it been collected in any previous surveys (Woolman 1890; Smith 1968). Results by Warren et al. (1994) mention creek chub (*Semotilus atromaculatus*), black spotted topminnow (*Fundulus olivaceous*), saddleback darter (*Percina vigil*), suckermouth minnow (*Phenacobius mirabilis*), and freckled madtom (*Noturus nocturnus*) were associated with the relict darter. All species mentioned have been collected in my results (Table 2). Warren et al. (1994) concluded that finding additional populations of the relict darter outside of the Bayou de Chien drainage was highly unlikely given the following: habitat affinities of the relict darter, the complete allopatry between the relict darter and its closest relatives, the complete absence of any other species in the *Etheostoma squamiceps* complex in the Mississippi River tributaries in Kentucky, and the previous surveys that did not record the relict darter outside of the Bayou de Chien drainage. Because the relict was not discovered in the upper Obion Creek drainage its endemism seems to be unique to Bayou de Chien (Warren et al. 1994).

SUMMARY

The results of my survey serve as an updated, comprehensive list and distribution of the fishes of the Obion Creek drainage in Western, Kentucky. My findings show an increase in species richness over the last 40 years and two additional exotic, highly invasive carp species. Hopefully, the updated list will serve as a starting point for further stream fisheries research in the Jackson Purchase area. The scores obtained from the Kentucky Index of Biotic Integrity on the Obion Creek drainage show the fair to poor health of the drainage that was determined by assessing fish communities. The fair to poor conditions of the drainage reflect a century's worth of poor land use and watershed management in the Jackson Purchase area. However, the results of this survey did show an increase in diversity over past surveys. I recommend a project similar to this one be done on the other major drainages of the Jackson Purchase area.

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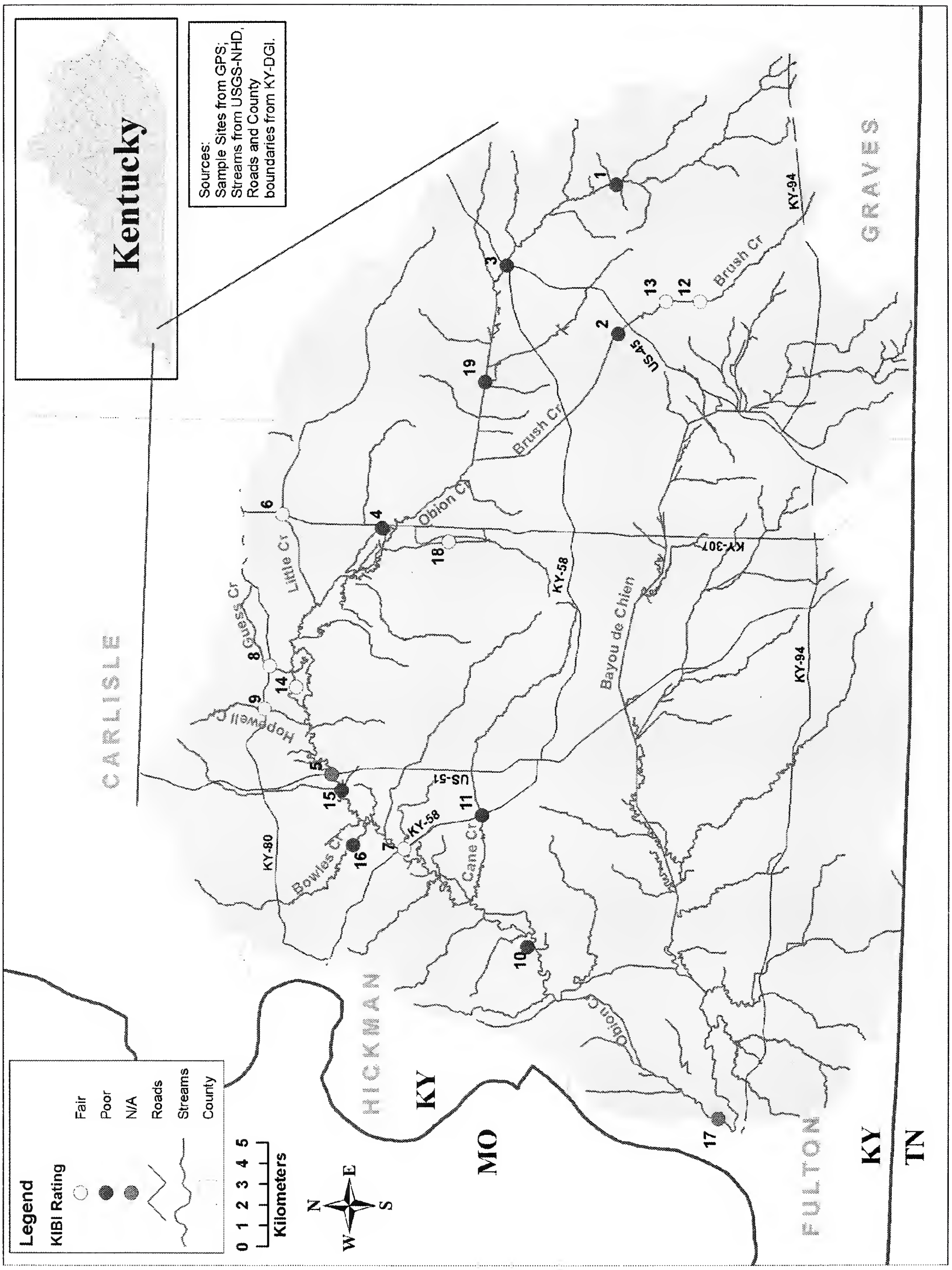

Figure 2. Sampled locations in the Obion Creek drainage with fair-poor KIBI ratings.

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Teleconnective relationships to the Kentucky Snowfall Impact Scale

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ABSTRACT

Heavy snowstorms in Kentucky, while uncommon, often shut down commerce and transportation networks while threatening public safety. An understanding of the teleconnection patterns associated with these storms could benefit many people in the state. In this study, we adapted a snowstorm ranking methodology originally developed for the northeastern United States and applied it to Kentucky. Transportation and population data were used along with snowfall data to rank 26 significant Kentucky snowstorms from 1960–2010. Our results showed that the snowstorm of 6 January 1996 barely edged out the storm of 9 March 1960 to rank as the worst storm in the past 51 winters. Heavy snowstorms in Kentucky tend to be clustered through time and often associated with the warm phase of the Pacific Decadal Oscillation and the negative phases of the North Atlantic Oscillation and Eastern Pacific Oscillation. However, analysis also suggests that several other teleconnection patterns can lead to heavy snowstorms in Kentucky.

KEY WORDS: Teleconnections, snowstorm, Kentucky Snowfall Impact Scale (KYSIS), El Niño – Southern Oscillation (ENSO), winter, Kentucky

INTRODUCTION

Winter snowstorms in the United States often wreak havoc on transportation networks and public safety to the point where the most extreme snowstorms cause damage in excess of $1 billion (Ross and Lott 2003; Changnon 2007). Heavy winter snowstorms occur with the greatest frequency in the northern-tier states stretching from the Plains into New England (Schwartz and Schmidlin 2002; Changnon et al. 2006). As expected, these northern-tier states easily cope with all but the largest of winter snowstorms because their cities are experienced and equipped for rapidly clearing transportation networks and have snow removal budgets in the millions of dollars. While large Kentucky cities such as Lexington and Louisville have comprehensive snow removal plans and are well equipped with numerous snowplows, most other regions of the state have a small number of snowplows, if any at all. Heavy snowstorms have been known to shut down even state highways in rural counties for up to a week. Thus, the infrequent nature of heavy snowfall events in Kentucky combined with minimal preparation can have devastating effects to commerce and transportation in the Commonwealth. Clearly research that could help forecasters develop a better understanding of the teleconnections patterns associated with major snowstorms in Kentucky would be of great benefit.

There have been few attempts to understand which teleconnections patterns are associated with heavy snowstorms in Kentucky and surrounding Mid-South states. Mote et al. (1997) conducted a snowfall climatology of the Southeast but did not include Kentucky. Hartley (1999) provided an overview of winter climate over the southern and central Appalachians, but made no attempt to categorize or rank heavy snow events. The National Weather Service office in Louisville posted preliminary results of a 15-year heavy snowfall climatology for Kentucky and southern Indiana on its website. They used composites of the storms in the 15-year study to discuss the synoptic features necessary to produce heavy snowfall in the region but did not attempt to rank or categorize the storms (Cox et al. 2004). Their research focused on two primary synoptic patterns. Pattern A was associated with weak surface and mid-level features along with strong isentropic lifting forced by a low-level jet, typically along a warm-frontal boundary. A polar jet streak centered over the Great Lakes with the right entrance region located over Kentucky allows for divergence aloft while maintaining arctic air at the surface. Pattern B was associated with strong surface and mid-level development. These storms typically feature slow moving closed-off lows

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in the upper levels of the atmosphere and an easterly flow at the surface. Mesoscale convective banding can occur during both patterns in the most extreme events. These two very different snowstorm patterns suggest that any number of atmospheric teleconnection patterns may possibly occur during a heavy snowstorm in Kentucky. A teleconnection represents a low-frequency preferred mean state of the atmosphere with known relationships to temperature and precipitation patterns in a particular region (Barnston and Livezey 1987). Teleconnections, which includes the well-known El Niño – Southern Oscillation (ENSO), have temporal scales from weeks to decades and spatial scales that are regional to global. What is presently unknown, however, is which combination of teleconnections occurs most frequently during significant snowstorms in Kentucky. To properly assess the climate teleconnections that influence heavy snowstorms in Kentucky, a time-scale longer than the 15-year climatology used by Cox et al. (2004) must first be developed. Therefore, this research first expanded upon the Cox et al. (2004) study by lengthening the historical snowfall climatology for Kentucky from 15 to over 50 years.

Walker et al. (2008) was a preliminary study that outlined a method for creating an historical snowfall climatology for Kentucky since 1960 as well as a method for objectively ranking the historical snowstorms. The Kentucky Snowfall Impact Scale (KYSIS) was adapted from Kocin and Uccellini (2004) who ranked historical snowstorms in the northeastern United States using the Northeast Snowfall Impact Scale (NESIS). The NESIS score is based on the population density affected by snowfall contours from each storm. This analysis first briefly summarized the updated historical snowfall climatology for Kentucky and the KYSIS methodology used in Walker et al. (2008). With the new KYSIS rankings, we used climate teleconnections of various spatial and temporal scales to ascertain which teleconnections were associated with major snowstorms in Kentucky from 1960–2010. While the analysis used only Kentucky snowfall data, the results should be applicable to the entire Mid-South region.

MATERIALS AND METHODS

Kentucky Historical Snowfall Climatology

Walker et al. (2008) described in detail the development of the Kentucky historical snowfall climatology. Heavy snow events were found using the *Storm Data* database maintained by the National Climatic Data Center (NCDC). *Storm Data* is a repository for climatic information that includes information on events including snowstorms, tornadoes, lightning, wildfires and droughts and is available online at http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?wwEvent~Storms as well in hardcopy form. Numerous sources gather data for *Storm Data* including storm spotters, emergency management, local National Weather Service offices, and the media. While *Storm Data* has a flaw in that it is a voluntary compilation of weather data, it is useful for the purpose of finding major events (Branick 1997; Dixon et al. 2005). Snowfall information from both the online and hardcopy versions of *Storm Data* were investigated to find winter storms that produced more than 10 cm of snow over at least one-half of Kentucky because that represents the criteria for a winter storm watch issued by the National Weather Service in Kentucky. Additionally, solar heating often will melt snow on road surfaces less than this amount within a few hours in Kentucky, even on days when temperatures remain below freezing.

Storm Data provides only a general description of each heavy snowfall with the dates of occurrence. To create detailed maps of each heavy snowfall, we then used the Midwest Climate Information System (MICIS) an online tool from the Midwestern Regional Climate Center (MRCC). Search functions in the MICIS database allowed us to aggregate snowfall totals for over 400 cooperative weather stations for each storm we found from *Storm Data*. Snowfall contour maps were created with GIS by using location information for each weather station. The original historical heavy snow climatology from Walker et al. (2008) contained 21 storms from 1960–2006. To account for any storms that pre-dated or otherwise were not included in *Storm Data*, we used additional searching capabilities within MICIS that allowed this updated climatology to contain 26 storms and to extend to 2010 (Table 1).

Table 1. Significant Kentucky snowstorms since 1960. Because some storms persisted over more than one day, the last day of recorded snowfall was used.

Snow event		
14 February 1960	7 January 1979	6 January 1996
2 March 1960	5 December 1984	1 February 1996
9 March 1960	5 January 1985	19 March 1996
23 January 1966	3 February 1985	3 February 1998
2 November 1966	13 February 1985	4 December 2002
29 December 1967	31 March 1987	23 December 2004
22 March 1968	25 February 1993	9 March 2008
9 February 1971	12 March 1993	30 January 2010
26 January 1978	18 January 1994	

KYSIS

In order to objectively rank the 26 snowstorms in the historical climatology, the next step was to modify the NESIS methodology used by Kocin and Uccellini (2004) and apply it to Kentucky. NESIS uses snowfall data mapped onto the population density of the Northeast urban corridor to objectively rank the impact of a storm on a population (Kocin and Uccellini 2004). Because Kentucky is a rural state with major population centers concentrated along the I-64 corridor between Louisville and Lexington, we also use length of highway impacted in addition to population density to help determine the KYSIS rankings. This allowed us to quantify the impact of a snowstorm on Kentucky's transportation network.

Contour maps of snowfall were created for each storm by spatially interpolating snowfall totals from each of the 400+ stations using ordinary kriging. Snowfall data from counties in states surrounding Kentucky were used in the interpolation to produce more realistic contour maps. The interpolated snowfall totals were classified into 0–10 cm, 10–20 cm, 20–30 cm, 30–40 cm, 40–50 cm, 50–60 cm, and >60 cm categories to aid in storm impact assessment. The formula to determine KYSIS takes the following form:

$$\mathrm{KYSIS} = \sum\nolimits_{n}^{x} [n(A_n/A_{mean} + P_n/P_{mean} + HW_n/HW_n)] \qquad (1)$$

In (1), n represented minimum snowfall amounts divided by 20 cm. Therefore, n = 0.5 was used for areas inclusive of the 10 cm contour, n = 1 was used for the 20 cm contour, n = 1.5 was used for the 30 cm contour, etc. The variable A_n, represented the estimated area (km^2) within each snowfall contour, and P_n and HW_n represented the population and length of highway (km) found in that area. Values of A_{mean}, P_{mean}, and HW_{mean} represent mean area, population, and length of highway found within the 20-cm contour. GIS estimated the area, population, and length of highway found within each contour by selecting all counties in which at least half of the county was analyzed to lie within the given contour line. Population values from the 2000 census and the 2005 length of highways from the Arc-GIS database were used to standardize the results to current values. The primary difference between the KYSIS and NESIS equations has to do with differences in what constitutes a winter storm watch between Kentucky and the Northeast. We use a smaller value for n = 1 (20 cm vs. 25 cm for NESIS) to account for lesser snowfall amounts in Kentucky and restrict the analysis to a single state (NESIS uses the total snowfall distribution east of the Rockies to compute values). KYSIS also includes the length of highways to account for impacts to Kentucky's transportation networks. As in Kocin and Uccellini (2004), categories were created to group storms of similar impact (Table 2). The 26 storms were ranked using KYSIS methodology (Table 3).

Table 2. KYSIS categories.

Category	KYSIS values	Cases	Description
5	>20.00	3	Extreme
4	12.00–19.99	2	Crippling
3	8.00–11.99	7	Major
2	4.00–7.99	6	Significant
1	<4.00	8	Notable

Table 3. KYSIS rankings and category since 1960.

Event	KYSIS	Category	Event	KYSIS	Category
6 January 1996	25.43	5	9 February 1971	5.73	2
9 March 1960	25.14	5	19 March 1996	5.51	2
18 January 1994	22.97	5	9 March 2008	5.12	2
12 March 1993	16.68	4	7 January 1979	4.53	2
3 February 1998	14.10	4	25 February 1993	4.28	2
22 March 1968	10.93	3	29 December 1967	3.90	1
3 February 1985	10.53	3	30 January 2010	3.71	1
14 February 1960	9.05	3	31 March 1987	3.33	1
2 March 1960	8.83	3	5 December 1984	3.09	1
2 November 1966	8.62	3	1 February 1996	1.97	1
13 February 1985	8.59	3	4 December 2002	1.80	1
23 December 2004	8.22	3	26 January 1978	1.60	1
23 January 1966	6.49	2	5 January 1985	0.54	1

Teleconnections

Seven teleconnection indices with temporal scales ranging from low to very low frequency were used to determine synoptic relationships with KYSIS events. These seven teleconnections have been linked to variations in snowfall or winter precipitation in the United States (Table 4). Low frequency teleconnections such as the North Atlantic Oscillation (NAO), Pacific North American pattern (PNA), and the Eastern Pacific Oscillation (EPO) vary inter-weekly to inter-monthly and often are associated with week-to-week changes in weather patterns (Barnston and Livezey 1987). All three have predictability limited to the scope of 1–15 day medium range weather forecast models. The NAO represents a dipole of geopotential height anomalies over the North Atlantic with the positive phase featuring above-average anomalies over the Azores and below-average anomalies over Greenland centered on 40°W. The PNA represents a quadripole of geopotential height anomalies with the positive phase featuring above-average anomalies over Hawaii and the northern Rockies and below-average anomalies over the Aleutians and the southeastern United States. The EPO represents a dipole of geopotential height anomalies over the eastern Pacific with below-average anomalies over the Gulf of Alaska and above-average anomalies over the tropical Pacific centered on 150°W.

The Niño3.4 index and the Southern Oscillation index (SOI) were used to represent ENSO, which varies inter-annually. The Niño3.4 index is calculated as the average of monthly SST anomalies for the area 5°N–5°S, 120°–170°W. Years of El Niño, La Niña, and neutral ENSO were calculated using the NOAA method to determine various ENSO events. This states that when the three-month moving average of Niño3.4 anomalies exceeds +0.5 (−0.5) for three consecutive months, an El Niño (La Niña) event is said to occur. All other periods were considered neutral ENSO. The SOI, which is negatively correlated with Niño3.4, represents the standardized differences of standardized sea-level pressure differences between Tahiti and Darwin, Australia. Finally, two very low-frequency teleconnections were used to represent multidecadal changes in the Atlantic and Pacific Oceans. The Atlantic Multidecadal Oscillation

Table 4. Teleconnections with links to variations in snowfall or winter precipitation.

Teleconnection	
Atlantic Multidecadal Oscillation (AMO)	Goodrich and Ellis 2008
East Pacific Oscillation (EPO)	Miller and Goodrich 2007
El Niño – Southern Oscillation (ENSO)	Kunkel and Angel 1999
North Atlantic Oscillation (NAO)	Seager et al. 2009
Pacific Decadal Oscillation (PDO)	Ge and Gong 2009
Pacific North American Pattern (PNA)	Morin et al. 2008

(AMO) is a mode of natural variability occurring primarily in sea surface temperatures in the northern Atlantic Ocean with a periodicity of 60–80 years. The Pacific Decadal Oscillation (PDO) is an ENSO-like pattern of northern Pacific Ocean sea surface temperature variability with a periodicity of around 50 years. The PDO index is defined as the leading principal component of northern Pacific Ocean monthly sea surface temperature variability poleward of 20°N latitude.

Monthly PDO data are available from the Joint Institute for the Study of the Atmosphere and Ocean at the University of Washington (http://jisao.washington.edu/pdo/PDO.latest). Monthly AMO data are available from the NOAA Environmental Research Laboratory (http://www.cdc.noaa.gov/Timeseries/AMO/), and in this case they represented unsmoothed, de-trended sea surface temperatures generated from the Kaplan sea surface temperature data base, version two. The monthly Kaplan extended Niño3.4 dataset was obtained from the International Research Institute for Climate prediction (IRI) data library and is available online at http://iridl.ldeo.columbia.edu/SOURCES/.Indices/.nino/.EXTENDED/.NINO34/. A small adjustment was made to the time series to change the base period climatology from 1951–1980 to 1971–2000. Monthly SOI data were obtained from the Climate Prediction Center and are available at http://www.cpc.ncep.noaa.gov/data/indices/soi. Daily data for the EPO, PNA, and NAO were obtained from the Climate Diagnostics Center but are not presently available online. Monthly data for the PNA and NAO were obtained from the Climate Prediction Center at ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/tele_index.nh.

RESULTS AND DISCUSSION

KYSIS Rankings

KYSIS represents a measure of the integrated impact of a snowstorm on transportation and population densities in Kentucky. With the increased weight given to higher snowfall amounts, the greatest KYSIS values should involve a statewide snow event with maximum snowfall values on the I-64 corridor between Louisville and Lexington. The same amount of snow over less densely populated areas should result in a lower score. The snowfall maps from the two top-ranked storms bear this out (Figure 1). The storms that occurred on 6 January 1996 (25.43) and 9 March 1960 (25.14) had nearly identical scores and together ranked as the worst snowstorms to affect Kentucky since 1960. Because KYSIS scores were dependent on GIS interpolation and other data assumptions, the two storms can be said to be in a statistical dead heat with regards to the title of "worst snowstorm." While the 9 March 1960 snowstorm had greater absolute snowfall totals (>75 cm in some areas) and easily was the worst snowstorm in southern Kentucky, the 6 January 1996 storm scored high due to heavy snow (>30 cm) along the I-64 corridor. These two storms along with the 18 January 1994 storm (22.97) that primarily affected areas along the Ohio river rank as the only Category 5 (Extreme) snowstorms since 1960 (Figure 2). All three snowstorms had over a million people and 16,000 km of highways impacted by at least 30 cm of snow. Each storm brought transportation and commerce to a standstill throughout the state for several days. Only one of the three Category 5 "extreme" storms (January 1996) ranked second overall behind the March 1993 Storm of the Century in Kocin and Uccellini (2004). The other two Category 5 storms had minimal impact on the Northeast urban corridor. The famous "Storm of the Century" March 1993 blizzard (16.68) that ranked highest using NESIS was only the fourth ranked storm using KYSIS and was one of only two Category 4 (Crippling) storms (Figure 2). This lower ranking for the "Storm of the Century" is an example of how the KYSIS methodology emphasizes storms that impact population centers versus more rural areas. The nine storms considered to be Category 4 (Crippling) or 3 (Major) were all either widespread with lower maximum snowfall amounts or had high maximum amounts that fell in less populated areas. The remaining 14 storms considered Category 2 (Significant) or 1 (Notable) all had snowfall generally in the 10–20 cm range and are considered nuisance events.

Frequency of KYSIS Events

The list of KYSIS events (Table 1) showed that heavy snowstorms in Kentucky tend to be

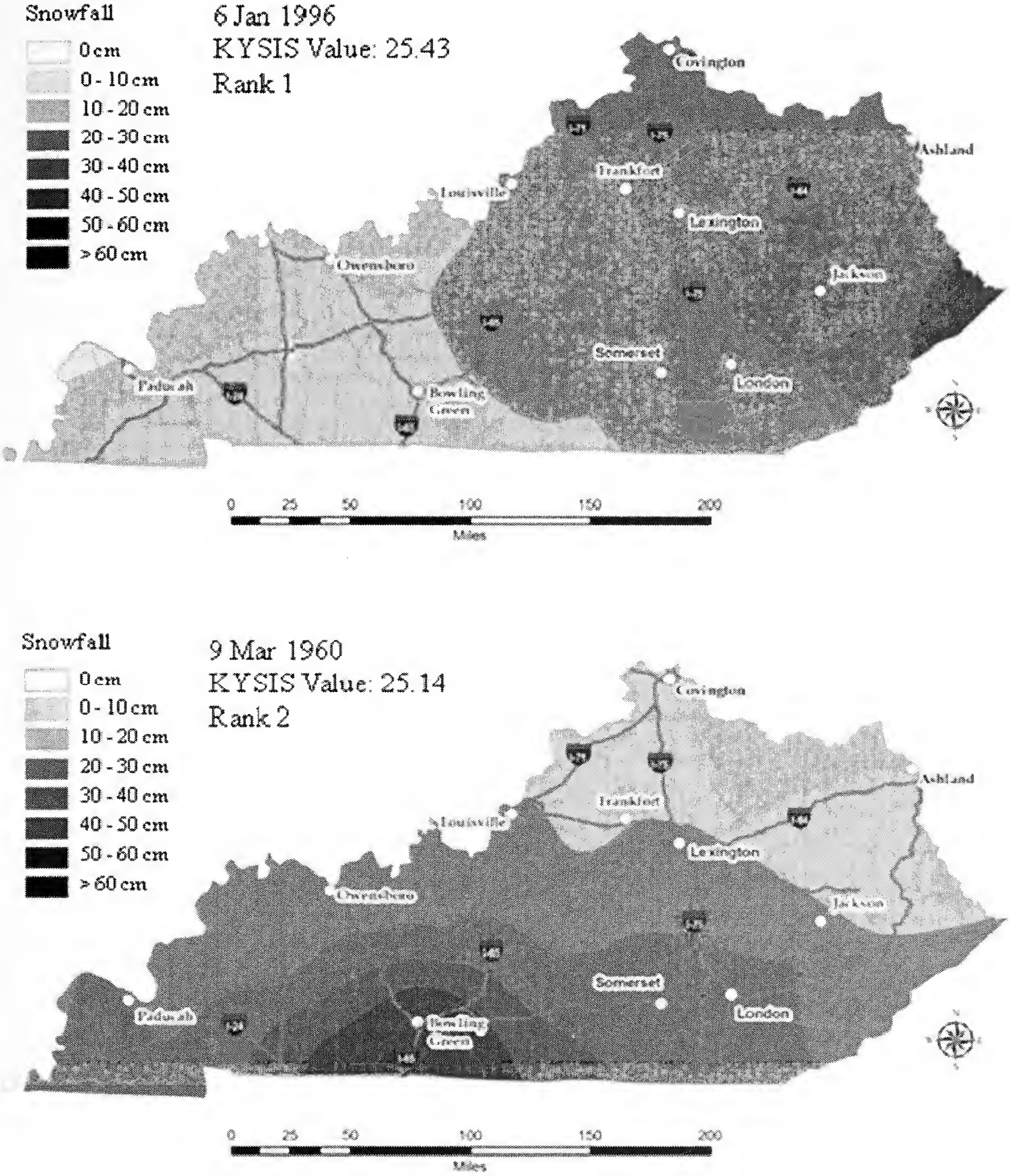

Figure 1. Snowfall contours and KYSIS values for the 6 January 1996 and 9 March 1960 snowstorms, the first and second ranked snowstorms in Kentucky since 1960.

clustered through time. This is confirmed by a chart of KYSIS events through time (Figure 3). Fourteen of the 26 storms (54%) occured during only five of 51 winters (10%). The winter of 1984–1985 experienced four storms, the winters of 1959–1960 and 1995–1996 each experienced three storms, and the winters of 1967–1968 and 1992–1993 each had two. Nearly half of the storms (12) occurred during the 14 winters from 1984–1985 to 1997–1998, which accounted for just 27% of the period of record and averaged close to a storm per year. That is in contrast with the previous 14 winters from 1969–1970 to 1983–1984 where only three storms occurred, none stronger than a Category 2. This marked an increase in

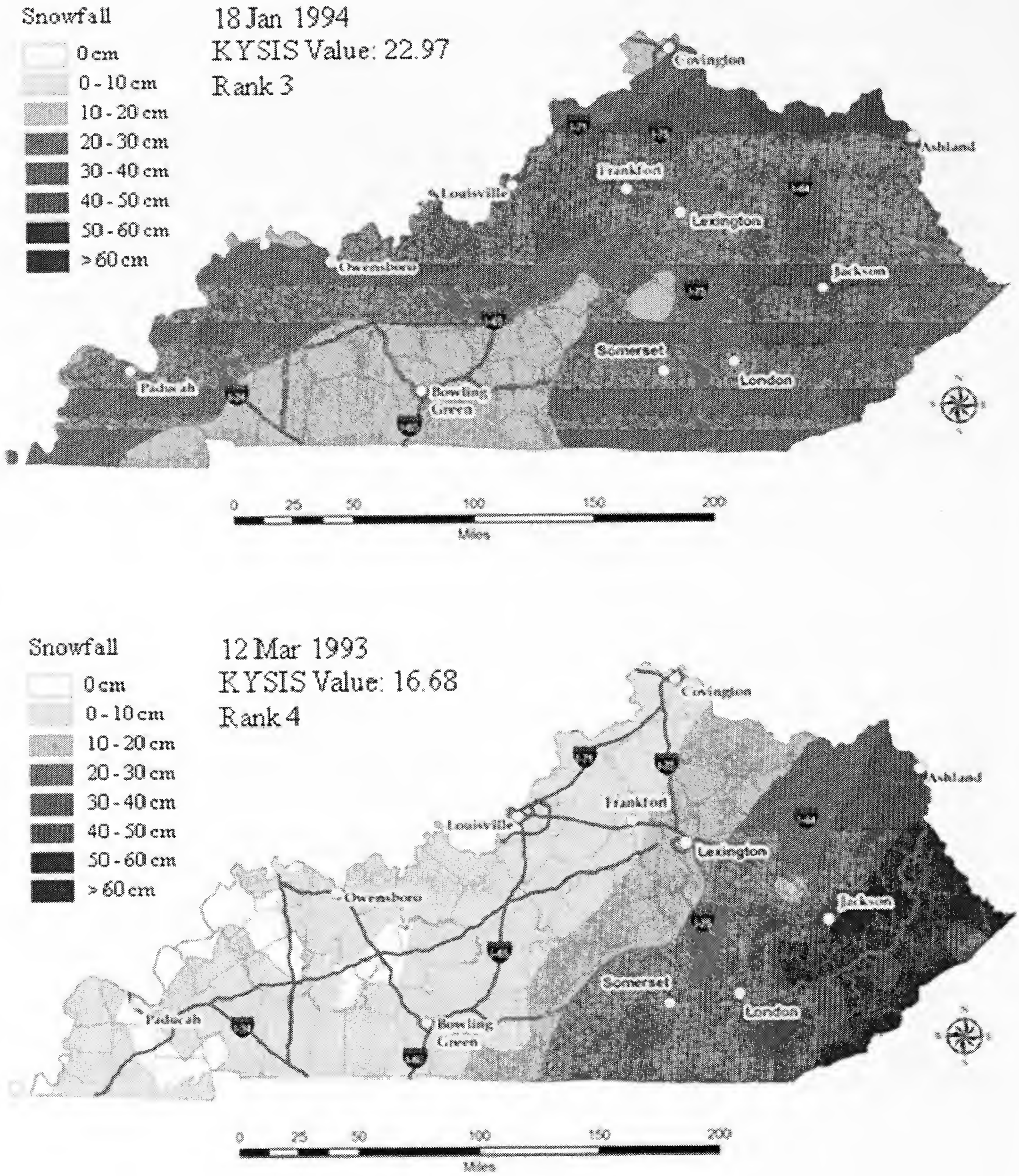

Figure 2. Snowfall contours and KYSIS values for the 18 January 1994 and 12 March 1993 snowstorms, the third and fourth ranked snowstorms in Kentucky since 1960.

the return frequency of KYSIS events from once nearly every five years in the 1970s and early 1980s to almost once a year to close out the century. Perhaps most notable is that four of the five "extreme" and "crippling" storms to affect Kentucky in the past 51 years occurred within a six-year period from 1993–1998. However, the past decade since 1998 has been relatively quiescent with only the 23 December 2004 and 9 March 2008 storms standing out as major events.

Teleconnective Relationship to KYSIS

The preliminary work of Cox et al. (2004) suggested there were at least two important patterns related to heavy snowfall in Ken-

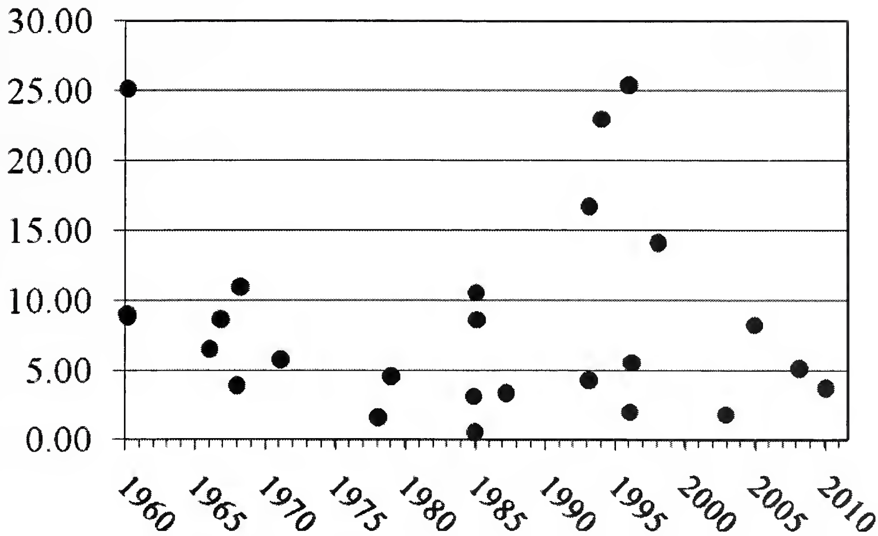

Figure 3. Time series of KYSIS values. Note: The 14 February 1960 (9.05) and 2 March 1960 (8.83) storms show up as one storm due to time scale resolution.

tucky, which implies there could be several different combinations of teleconnection phases. Therefore, we wanted to use several teleconnections that are known to impact winter weather in the eastern United States of various spatial and temporal scales (Table 4). The seven teleconnections included in this study have temporal variability that ranges from inter-weekly (NAO, PNA, EPO) to inter-annual (Niño3.4, SOI) to multi-decadal (PDO, AMO) and spatial variability that ranges from the tropical Pacific (Niño3.4, SOI) to the extratropical Pacific (PDO, EPO, PNA) to the extratropical Atlantic (NAO, AMO). Because it already has been established that KYSIS events tend to be clustered through time (Figure 3), the first step in the analysis was to compare the mean values for each teleconnection during winters with a KYSIS event (15 winters) with those without (32 winters). Because nearly all (25 of 26) of the KYSIS events occurred during the months of December–March (DJFM), seasonal teleconnection values were averaged over this 4-month period. None of the seven teleconnections had difference of means values that approached standard thresholds of statistical significance ($\alpha = 0.05$) (Table 5). Most teleconnections on a seasonal basis averaged close to zero regardless of whether or not a KYSIS event occurred. The main exceptions were the PDO ($\rho = 0.09$) and NAO ($\rho = 0.11$) that displayed non-significant tendencies to be in the warm phase and negative phase respectively during KYSIS winters compared with non-KYSIS winters. Thus, the increase of KYSIS events during the 1980s and 1990s may be partially explained by the warm phase of the PDO that occurred from 1977 to at least 1998 (Hare and Mantua 2000). While it was expected that the other inter-weekly teleconnections (PNA, EPO) were not important on a seasonal basis, it was somewhat surprising that none of the ENSO phases were favored. ENSO phases during KYSIS winters occurred with roughly the same frequency as during non-KYSIS winters. When the seasonal analysis was repeated using only the teleconnection averages during the core winter months of January-February for KYSIS and non-KYSIS winters, the negative phases of both the NAO ($\rho = 0.01$) and the EPO ($\rho = 0.12$) emerged as common during KYSIS winters.

Because the seasonal analysis did not provide much insight, we repeated the analysis using monthly averages of the seven teleconnections during winter (DJFM) months of KYSIS and winter months without KYSIS (Table 5). The multidecadal (PDO, AMO) and inter-annual (Niño3.4, SOI) results did not change much from the seasonal analysis because by nature these teleconnec-

Table 5. Mean teleconnection values during seasons, months, and days (five days surrounding) with KYSIS events compared with winter (DJFM) seasons, months, and days without KYSIS events. Statistically significant ($\rho < 0.05$) difference of means by *t*-test are italicized.

Season		NAO	PNA	EPO	SOI	Nino34	PDO	AMO
	mean	−0.17	0.14	−0.05	−0.44	0.21	0.32	−0.02
KYSIS	SD	0.64	0.57	0.37	1.21	1.07	0.94	0.19
	N	17	17	17	17	17	17	17
	mean	0.16	0.16	0.10	−0.05	−0.02	−0.16	−0.04
No KYSIS	SD	0.71	0.68	0.35	1.13	0.93	0.94	0.18
	N	34	34	34	34	34	34	34
	ρ	0.11	0.92	0.19	0.16	0.43	0.09*	0.99
Monthly		**NAO**	**PNA**	**EPO**	**SOI**	**Nino34**	**PDO**	**AMO**
	mean	−0.24	0.12	−0.27	−0.44	0.12	0.37	−0.04
KYSIS	SD	0.85	0.93	0.66	1.10	1.02	0.99	0.18
	N	24	24	24	24	24	24	24
	mean	0.09	0.15	0.09	−0.14	0.05	−0.02	−0.03
No KYSIS	SD	1.03	0.97	0.67	1.41	1.00	1.05	0.19
	N	181	181	181	181	181	181	181
	ρ	0.13	0.89	*0.02*	0.32	0.75	0.09*	0.99
Daily		**NAO**		**PNA**		**EPO**		
	mean	−0.16	17 < 0	0.20	10 < 0	−0.70	18 < 0	
KYSIS	SD	0.71	9 > 0	0.60	16 > 0	1.40	8 > 0	
	N	130		130		130		
	mean	0.11		0.13		0.06		
No KYSIS	SD	0.80		0.76		1.44		
	N	6029		6029		6029		
	t	3.8		1.0		5.7		
	ρ	*0.0001*		0.29		*0.0001*		

* denotes $\rho < 0.10$ but >0.05.

tions have high month-to-month persistence. Of the inter-weekly teleconnections, the PNA once again had no relationship to KYSIS using monthly averages, but the NAO ($\rho = 0.13$) and especially the EPO ($\rho = 0.02$) favored the negative phase, both of which translated to an East Coast trough. Because monthly averages of inter-weekly teleconnections did not fully capture the state of the atmosphere in the days surrounding a heavy snowstorm, the analysis was repeated a final time using daily data for the NAO, PNA, and EPO. The daily teleconnection values averaged over the five days surrounding each KYSIS event (two days before and after the event) were calculated and then compared with all other winter days (DJFM) with no KYSIS events (Table 5). Once again, both the NAO (−0.16 with KYSIS and 0.11 without KYSIS; $\rho < 0.0001$) and EPO (−0.70 with KYSIS and 0.06 without KYSIS; $\rho < 0.0001$) were most commonly in the negative phase (East Coast trough) during KYSIS events. However, there have been several KYSIS events where at least one of the two teleconnections and sometimes both were in the positive phase (20 March 1968 and 23 February 1993). The NAO was negative during 17 of 26 of KYSIS events, and the EPO was negative during 18 of 26 events; both were negative at the same time only 50% of the time. The teleconnection values for the five highest scoring storms showed that there are many different ways to get heavy snow in Kentucky (Table 6). This shows that while teleconnections appear to provide some guidance as to when a heavy snowstorm may occur, they cannot predict the intensity of the snowstorm. While the majority

Table 6. Daily averaged (five days surrounding) teleconnection values for five highest KYSIS storms.

Date	KYSIS	NAO	EPO	PNA
6 January 1996	25.43	−0.65	0.66	0.20
9 March 1960	25.14	−0.06	0.90	−0.28
18 January 1994	22.97	0.74	−1.31	−0.18
12 March 1993	16.68	0.19	−2.18	−0.26
3 February 1998	14.10	−0.30	−0.71	0.76

of the 26 KYSIS events occurred with an East Coast trough related to the negative phase of either the NAO or EPO, heavy snow in Kentucky is possible in a zonal flow due to isentropic lift along a warm front if boundary layer conditions are just right (Cox et al. 2004). Finally, while the PNA was not a significant factor in the daily analysis, it should be noted that 16 of 26 KYSIS events occurred during positive PNA, which, like the negative phases of the NAO and EPO, teleconnects to an East Coast trough.

CONCLUSIONS

This research represented an attempt to create a climatology and methodology to rank historical snowstorms in Kentucky as well as to identify teleconnection patterns associated with the storms. The Kentucky Snowfall Impact Scale (KYSIS) is updated from Walker et al. (2008) to rank and categorize 26 heavy snow events from an historical snowstorm climatology. Using the area, population, and length of highways impacted by weighted snowfall contours, KYSIS objectively determined the worst snowstorms in Kentucky since 1960. The storms of 6 January 1996, 9 March 1960, and 18 January 1994, all rank as the worst snowstorms since 1960. The March 1993 blizzard, considered the "Storm of the Century," ranked only fourth in the analysis because that the heavy snowfall occurred primarily in the less populated eastern one-third of the state. KYSIS events tend to occur in clusters through time; nearly half of the 26 snowstorms occurred during only 27% of the period of record (1985–1998). In addition, nearly 55% of the 26 snowstorms occurred during only five of the 51 winters with the winter of 1984–1985 experiencing four major snowstorms. Of the five worst snowstorms in the rankings, four occurred during a six-year period from 1993–1998. On seasonal scales, the warm phase of the PDO and the negative phase of the NAO were non-significantly compared with KYSIS events. On monthly and especially daily scales, both the negative phases of the NAO and the EPO, which teleconnects to an East Coast trough, were significantly related to KYSIS events. However, there are several KYSIS storms that do not fit this pattern and occurred with a more zonal flow.

ACKNOWLEDGEMENTS

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Mössbauer Study of Iron Rich Cereal and Iron Supplement

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ABSTRACT

Mössbauer spectroscopy and X-ray diffraction measurements were performed on commercial iron rich cereal and on an iron supplement at room temperature. X-ray diffraction patterns of the raw cereal showed it to be more of an amorphous compound while the iron supplement was found to be in a crystalline form. Mössbauer spectra of the raw cereal showed about 81% of the iron in the ferric phase (Fe^{+3}), 18% in the metal form (Fe), and less than 1% in the ferrous phase (Fe^{+2}). Mössbauer spectra of the extracted iron from the raw cereal showed about 29% in the ferric phase, 70% in the metal phase, and less than 1% in the ferrous phase. Mössbauer measurements of the iron supplement showed 100% of the iron to be in the ferrous phase. The bioavailability of iron is generally attributed to the solubility of iron that is dependent on the oxidation state of iron in food and iron supplements. This study suggested that iron-rich cereal might not be the optimum source of iron for humans.

KEY WORDS: Mössbauer, iron supplement, iron rich, cereal

INTRODUCTION

Iron (Fe) is the end element of the fusion process of the life cycles of stars and the most abundant element in the core of red giants. It is the sixth most abundant element in the universe (Burbidge et al. 1957). Iron is believed to constitute 35% of the Earth, mostly in the core. On the surface of the earth it is found in the form of the hematite (Fe_2O_3) iron ores. Iron resides in group eight and period four of the periodic table. Iron has an atomic number of 26 with the electronic configuration $(Ar)3d^6 4S^2$. Iron can exist in many oxidation states but the two common ones are ferrous Fe^{+2} and ferric Fe^{+3}. The state of iron plays an important role in many biological molecules such as proteins and hemoglobin. With low levels of iron (anemia), the body cannot produce normal amounts of hemoglobin and in turn less oxygen is transported to the cells of the body, hence less energy is available for growth and performing bodily functions (Maton et al. 1993).

Free iron ions can be toxic; therefore, iron that is available to the body must be in the non-toxic ferrous state (Fe^{+2}) rather than the ferric state (Fe^{+3}) before assimilation in the blood stream (Jeppsen et al. 1999; Davisson et al. 2000). It was reported that toxic side effects were more severe with ferric salts because the absorption of ferric iron is relatively slower than the ferrous state (Sud et al. 1988). The U.S. Food and Drug Administration (FDA) agency requires that ferrous fumarate should not contain more than 2% of ferric iron (Food and Drugs, Sec. 172.350). Therefore, the knowledge of the state of iron that is to be consumed in cereals and iron supplements is of great importance as it may determine its biological effects as well as its toxicity.

Mössbauer spectroscopy is a sensitive technique in determining the iron oxidation state in solid compounds that contain iron. Mössbauer spectroscopy has been applied in biomedical research, particularly for analysis of iron containing pharmaceutical compounds (Oshtrakh 1991, 1999, 2004).

This study examined the oxidation state of iron in iron rich cereals, and the results were contrasted with iron-supplement pills for comparison. Room temperature Mössbauer measurements were carried out on raw cereal, on iron that was extracted from the cereal, and on one iron supplement pill.

METHODS

Material and Sample Preparation

A few cups of iron enriched Bran Flakes™ cereal were pulverized using a mortar and a pestle. Following pulverization, a 1000-ml glass beaker was filled with 600 ml of tap water and heated to a temperature of approximately 75°C. Approximately 75 ml of pulverized bran cereal was added to the 600 ml

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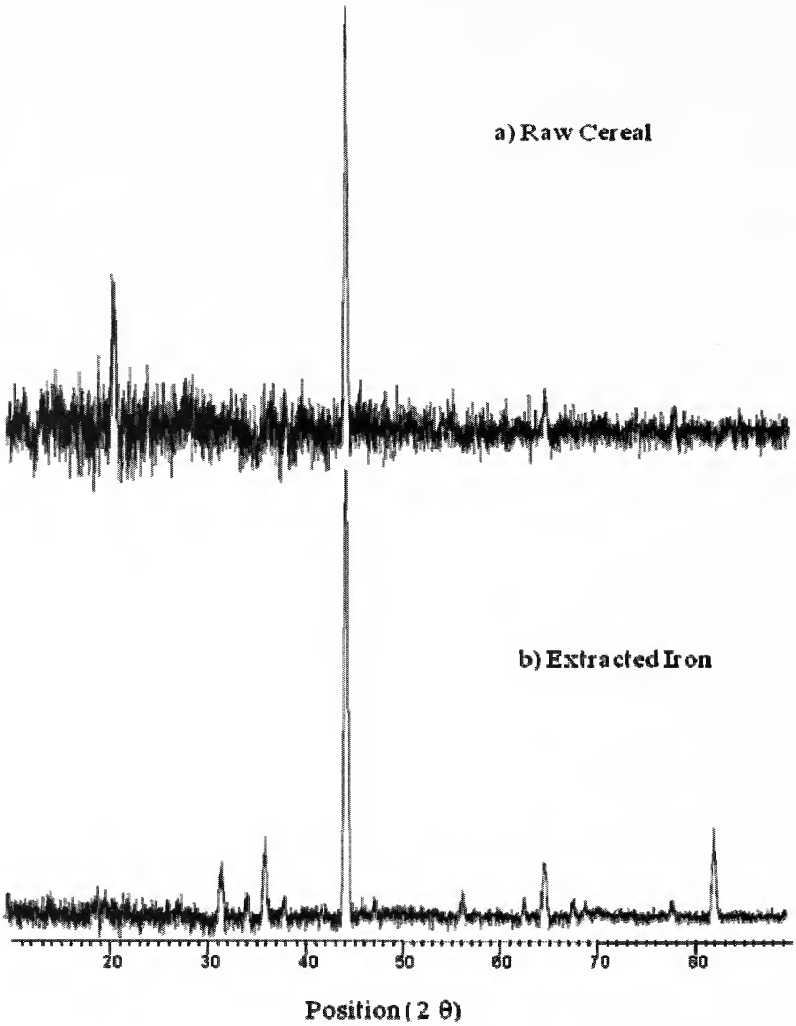

Figure 1. X-ray diffraction patterns of raw cereal (a) and of extracted iron from the cereal (b). The patterns of the extracted iron are consistent with metal iron.

of water and stirred with a wooden spoon for about 5 min in order to dissolve the cereal. Heating the water enabled the pulverized cereal to dissolve more rapidly, and it was observed that the amount of iron extracted also increased in relation to the amount of cereal dissolved in the water.

Once dissolved, the beaker containing the cereal solution was situated atop a strong horseshoe magnet and held in place by hand while the stirring continues for 2–3 min. The poles of the magnet made physical contact with the base of the beaker. Carefully, while continuing to support the beaker, both the magnet and the beaker were simultaneously lifted and the cereal solution poured slowly into an empty 1000-ml beaker. It was imperative that the base of beaker remained in contact with the poles of the magnet throughout the pouring process. As the solution was transferred from one beaker to the other, a small concentration of dark iron filings was observed to be clumped into a small region corresponding to the poles of the magnet. An aluminum scraper was used to clean away any undissolved larger particulates of remaining cereal, leaving behind a small clump of extracted iron. Coffee filter paper was used to remove the small iron clump. Coffee filter paper allowed any remaining moisture to be

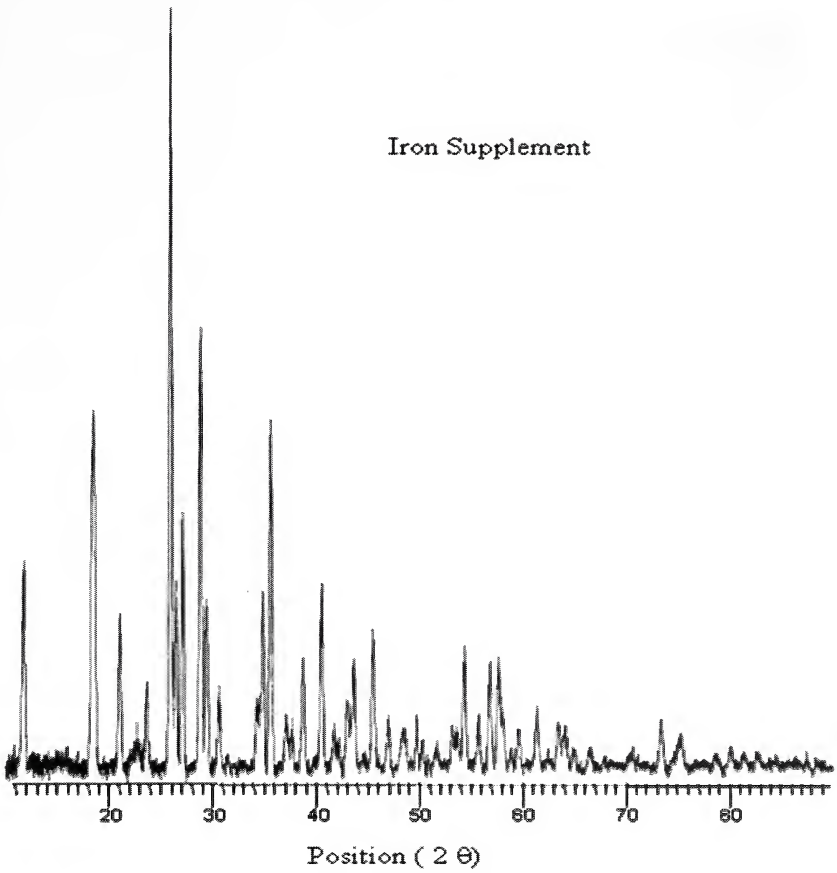

Figure 2. X-ray diffraction patterns of iron supplement pills. The patterns are consistent with $FeSO_4$.

absorbed although not allowing a significant portion of the miniscule iron filings to be absorbed. An aluminum scooping tool was used to transfer the iron clump from the filter paper onto a glass microscope slide where it was allowed to air dry. Once dried, the iron was scrapped into a mortar and pestle and re-pulverized to break down any clumps, and some of the sample was loaded in a small sample holder that was placed into the Mössbauer Spectrometer. The remainder was used for x-ray diffraction analysis.

The iron supplement 65 mg pill (which is equivalent to 325 mg of iron sulfate) used for comparison was manufactured by Pharmavite LLC of Mission Hill, CA.

X-ray and Mössbauer Measurements

A commercial X'pert X-ray diffraction system made by Philips was used to collect data for crystal structure identification. X-ray spectra of the raw cereal indicate that raw cereal can be characterized as an amorphous compound (Figure 1a). X-ray spectra of the extracted iron are consistent with that of a metal iron (Figure 1b). The x-ray patterns of the iron supplement are consistent with those of $FeSO_4$ which is the primary ingredient of the supplement pill (Figure 2).

Absorption Mössbauer data were taken at room temperature using a Wessel Mössbauer spectrometer (MVT 1000). About 4 miC of $^{57}Co(Rh)$ source was used in accumulating the data in a sinusoidal mode. More than a million counts were accumulated over several days of the raw cereal and the extracted iron samples. All Mössbauer data were referenced and calibrated to metallic iron (Figure 3). Mössbauer data were fitted using the commercial fitting program Recoil. The resulting fitting parameters of the isomer shift (I.S.), the quadrupole splitting (Δ), and the hyperfine

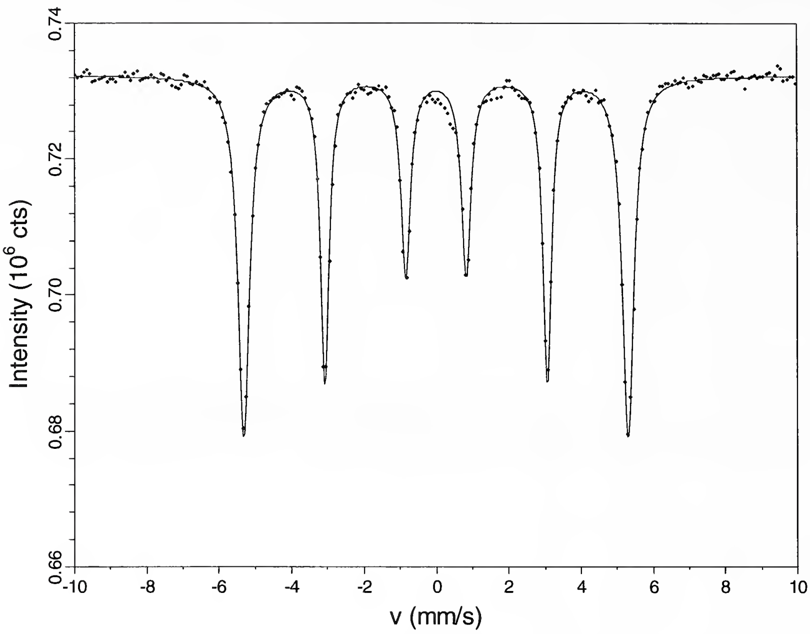

Figure 3. Mössbauer spectrum of metallic iron at room temperature used for reference and calibration.

magnetic field (hmf) of all Mössbauer data were tabulated (Table 1).

RESULTS AND DISCUSSION

The Mössbauer data of the raw cereal clearly showed a magnetic splitting as determined by the six absorption lines in addition to a quadrupole effect as represented by the doublet in the middle of the Mössbauer spectrum (Figure 4). The Mössbauer data of the raw cereal were fitted with one sextet and one doublet (Table 1). The quadrupole value of the doublet (0.289 mm/sec) suggested that the oxidation state of the iron in raw cereal was the undesirable ferric (Fe^{+3}) plus 3 oxidation state. This quadrupole value is consistent with that reported in the literature (Oshtrak 1999, 2004). The ferric doublet constituted about 83% of the available iron in the raw cereal. About 17% of the available iron in the raw cereal was metallic iron.

The Mössbauer data of the extracted iron showed that the Fe^{+3} doublet constituted about 30% of the total iron (Figure 5). This difference in the amount of Fe^{+3} appeared to be due to the method of the iron extraction. In either case, our study suggests further Mössbauer measurements on iron supplements. The Mössbauer measurements of the iron

Table 1. Summary of the fitting routine (Recoil) results of the Mössbauer data. I.S. is the isomer shift (mm/sec), Δ is the quadrupole splitting (mm/sec), and hmf is the hyperfine magnetic field (mm/sec and Tesla). The accepted value of the hmf in iron is 33 T.

Sample	I.S. (mm/sec)	Δ (mm/sec)	hmf (mm/sec, T)	% Site Population
Metal Iron	−0.003 ± 0.002	0.000 ± 0.002	2.237 ± 0.001 (32.952 ± 0.017 T)	100
Raw Cereal Doublet	0.225 ± 0.004	0.289 ± 0.007	—	82.7
Raw Cereal Sextet	−0.018 ± 0.032	0.024 ± 0.032	2.230 ± 0.015 (32.850 ± 0.220 T)	17.3
Extracted Fe^{+3} Doublet	0.363 ± 0.007	0.738 ± 0.001	—	31.58 ± 0.94
Extracted Fe^{+2} Doublet	1.536 ± 0.018	2.841 ± 0.035	—	0.55 ± 0.85
Extracted Fe Sextet	−0.001 ± 0.0003	0.001 ± 0.0003	2.234 ± 0.015 (32.895 ± 0.011 T)	67.87 ± 0.24
Iron supplement	1.257 ± 0.005	2.690 ± 0.001	—	100

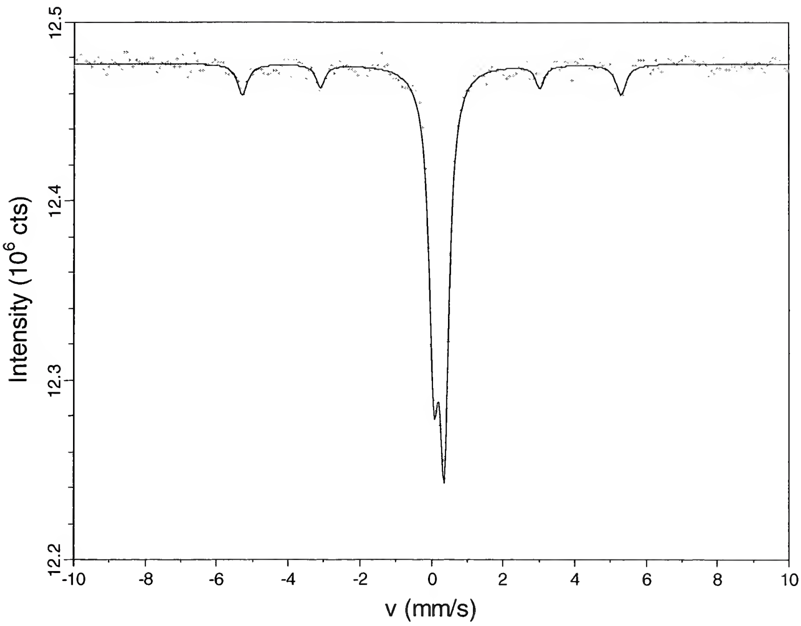

Figure 4. Iron Mössbauer spectrum of raw cereal. Data were fitted with one sextet and one ferric doublet.

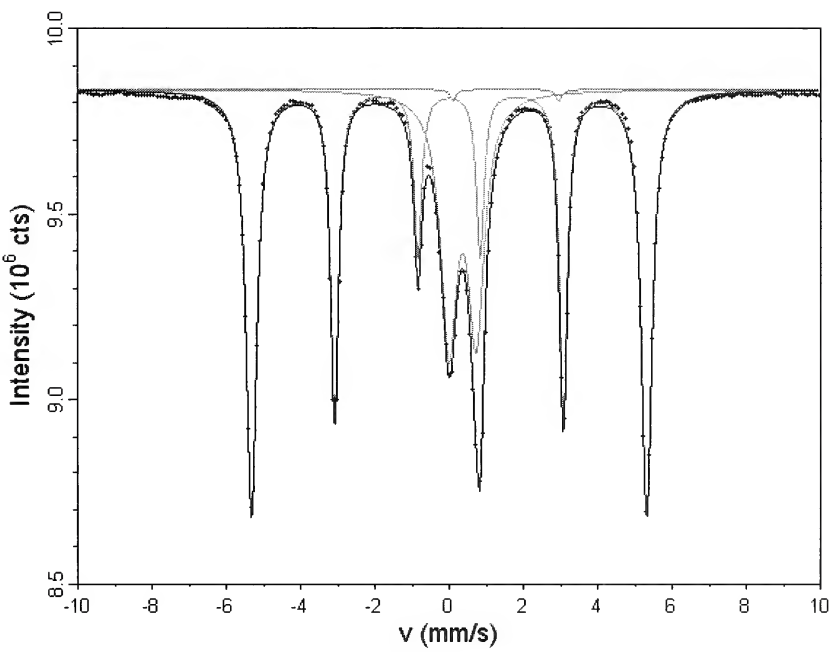

Figure 5. Iron Mössbauer spectrum of the extracted iron from the cereal. Data were fitted with one sextet and two doublets. The top small doublet represents the ferrous iron (Fe^{+2}) state while the middle more pronounced doublet represents the ferric iron (Fe^{+3}) state.

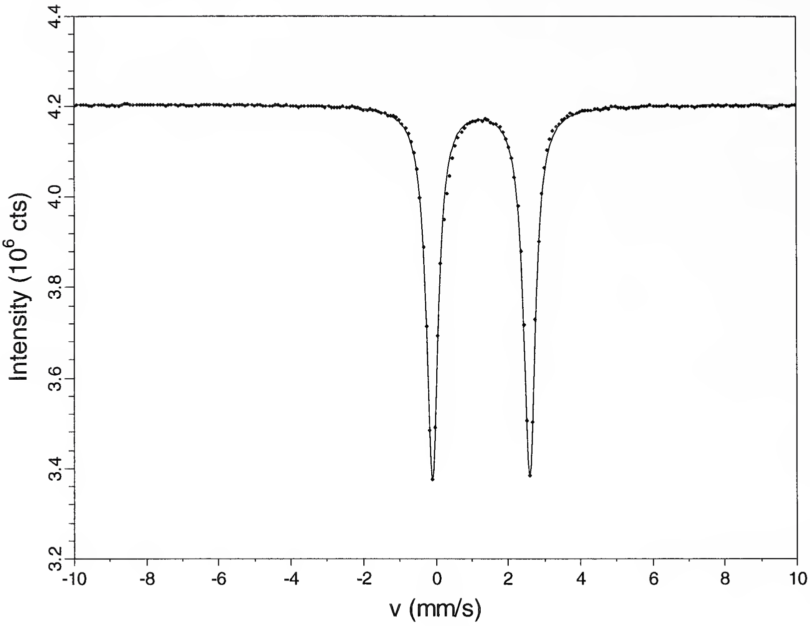

Figure 6. Iron Mössbauer spectrum of the iron supplement. Data were fitted with one pure ferrous iron (Fe^{+2}) doublet.

supplements showed that the oxidation state of iron is about 100% ferrous (Fe^{+2}) and the quadrupole value was consistent with the literature values of $FeSO_4$ (Figure 6) (Oshtrakh 2004).

To further understand the oxidation states of iron in raw cereal, the Mössbauer data of the extracted iron were fitted with two sets of doublets, one representing the ferrous iron state and the other representing the ferric state (Figure 5). Such fits produced a difference of only about 0.5% as a possible phase of the ferrous iron (Table 1). This supports the conclusion that most of the iron which is in the commercial iron-rich cereal is in the less useful ferric (Fe^{+3}) state.

CONCLUSIONS

The raw cereal was found to contain about 81.5% ferric phase, possibly less than 0.5% ferrous phase, and about 18% iron metal. In the extracted iron from the cereal, about 70% of the iron available for the body was in a metal form and about 30% constituted the ferric toxic state of iron. Further studies are needed on iron in cereals in general. In the iron supplement; however, the iron was almost 100% ferrous phase.

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Hispanic Consumer Perceptions of Kentucky-Grown Pigs

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ABSTRACT

Data were collected via a 2010 survey of Hispanic consumers in Kentucky regarding their willingness to purchase pigs from local growers. Focus was given on live animal sales because of the convenience of small-scale livestock producers. Results show that nearly 30% of respondents were willing to buy live pigs; however, only 13% of surveyed consumers were willing to process the live animals. The most popular size of pig was from 4.5 kg (10 lbs) to 18 kg (40 lbs). Hispanic consumers who lived with their families in Kentucky and/or were willing to travel to farms to purchase food products exhibited a significantly higher proclivity to buy pigs. Hence, the data indicated a strong potential for developing a direct-to-consumer market for pigs in Kentucky, particularly if farmers can cooperate with local butchers such that Hispanic consumers could conveniently buy live pigs and have them processed to their specifications.

INTRODUCTION

Pig farming is part of Kentucky's small-scale agricultural tradition, although the total production had diminished significantly from 138,000 farms in 1950 to only 900 farms in 2006 (USDA: NASS 2007). Marketing from small-scale farms is usually a challenge due to the relative high unit costs of production and low output volume. Small-scale Kentucky farmers have been successful in selling various products via direct-to-consumer markets or farmers markets (Dasgupta et al. 2010b). One direct-to-consumer market that is available to Kentucky's producers is the Hispanic consumer market. Anecdotal evidence from farmers and marketing research data simultaneously indicate that many Hispanic consumers are willing to purchase food directly from farms, including live animals (Sande et al. 2005; Dasgupta et al. 2010a). The Hispanic population in Kentucky has been expanding rapidly; in 2000 the Hispanic population in Kentucky was 59,939 (1.39% of Kentucky population), and the estimated Hispanic population in 2009 was 103,538 (2.56% of Kentucky population) (U.S. Census Bureau). Hence, if Kentucky producers could access the Hispanic communities for direct marketing, it would be good news for enhancing profitability for Kentucky's small scale producers.

This paper reports the perceptions of Kentucky's Hispanic consumers towards purchasing pigs locally. Data for this study were obtained via a Hispanic consumer survey as part of a USDA-Agricultural Marketing Service: Federal-State Marketing Improvement Program grant. Results of this paper could be useful tools to delineate the marketability of pigs to Hispanic consumers in Kentucky.

REVIEW OF RELEVANT LITERATURE

During the 1990s, the hog-pork sector in the United States underwent dramatic change with the expansion of large-scale, industrial operations. Since this time, the large-scale corporately-owned hog operations have dominated the market making it challenging for small scale pig farmers to compete using conventional production and marketing meth-

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ods (Ikerd 2001). Consequently, small scale farmers needed different approaches to pig marketing to remain competitive.

One alternative is direct-to-consumer markets that target Hispanic consumers. In research by the USDA, the Continuing Survey of Food Intakes by Individuals (CSFII) found that typically Hispanics ate pork at about the same rate as the rest of the U.S. population, but they have a significant preference for fresh pork products over processed meats (Davis and Lin 2005). Other data showed that Hispanic consumers prefer whole carcasses over specific cuts of pork (Value added agriculture program 2010). For example, in Mexican-American cooking, the spine bone is used for stews. This bone is only available in a whole carcass. Whole carcasses also provide pig skin and pig head that are used for various Hispanic dishes (Value added agriculture program 2010). While whole carcasses are difficult to obtain from large meatpackers, small-scale pig producers might be able to supply live pigs/whole carcasses to Hispanic consumers.

The Hispanic population in the United States has been increasing sharply; there has been a 33% increase from 35.2 million in 2000 to 46.8 million in 2008 (Dockterman and Velasco 2010). It is projected that by 2020 36% or one-in-four people in the United States will be Hispanic, making this ethnic group the largest and fastest growing in the country (Berry 2009). Kentucky has seen a dramatic increase in Hispanic population with a 72% growth from 2000 to 2008 (Kentucky Quick Facts 2008).

Hispanics have been found to spend more money on food purchases than the average American consumer (Wagner and Soberon-Ferrer 1990; Fan and Zuiker 1998; Paulin 1998; Paulin 2001). In general, Hispanics spend an average of \$133 per week on groceries as compared with \$93 spent per week by non-Hispanics. Hispanics have shown distinctive food preferences including the preference for fresh and authentic ingredients. Hispanics were more likely to cook meals at home than their non-Hispanic counterparts which translated to their spending 16.4% more on meat than non-Hispanic consumers (Diaz-Valensuela et al. 2008). Hispanic consumers in the United States are heavily influenced by the dietary patterns of their home countries with flavor and family-pleasing qualities being the primary attraction to certain foods. While cuisine can vary dramatically among countries of origin, many Hispanics retain the core elements of a Hispanic diet.

MATERIALS AND METHODS

Data for this study came from a 2010 survey of Hispanic consumers in Kentucky. The survey questions were designed after discussions with a Hispanic focus group consisting of consumers, restaurateurs/caterers, and cooperative extension personnel serving Hispanic communities. The survey questionnaire was tested by members of the focus group to ensure relevancy. The survey was conducted by face-to-face interviews during which consumers answered questions regarding 1) grocery shopping habits and willingness to purchase food products from farms or "farmers' market alternatives," 2) willingness to purchase pigs, and 3) consumer demographics. A total of 144 useful observations were obtained from the survey including demographic data (Table 1).

Consumer preference data were analyzed by statistically comparing proportions exhibited by various demographic groups towards their willingness to buy pigs in Kentucky. It was hypothesized that consumer demographics and shopping habits might exert a systematic influence over their preference towards buying pigs. Variables related to consumer demographics and shopping habits were used as independent variables in a logistic regression model (equation 1) where the dichotomous dependent variable exhibited respondents willingness to buy live pigs (Greene 1993).

(1) P[consumer i is willing to buy live pigs] = $\Lambda(\boldsymbol{\beta}_j' \times \mathbf{X}_i)$, where Λ represents the Logistic cumulative distribution function, $\boldsymbol{\beta}_j$ represents a $(k \times 1)$ vector of regression coefficients for the j^{th} attribute of a product, and $\mathbf{X}_i$ represents a $(k \times 1)$ vector of consumer characteristics, as discussed above.

By applying (1) to our data, we developed a logistic likelihood function that was maximized by selecting the appropriate $\boldsymbol{\beta}_j$s. These

Table 1. Distribution of demographic information expressed as a percentage of total respondents. U.S. Hispanic population demographics provided for comparison purposes. N = 144.

	Our data[a]	U.S. Hispanic population[b]
Gender:		
Male	45%	51%
Female	47%	49%
Age:		
30 or less	41%	57%
31–40	31%	17%
41–50	13%	13%
51–60	3%	7%
61–65	1%	2%
66 or more	0%	4%
Education:		
High school or below	67%	71%
Technical	18%	___[c]
4-year degree or more	7%	10%
Country of Origin:		
Mexico	65%	65%
Honduras	6%	1%
Guatemala	4%	2%
El Salvador	3%	3%
Nicaragua	3%	1%
Other	9%	28%
Household income:		
Less than $20K	52%	20%
≥$20K but <$30K	28%	15%
≥$30K but <$40K	10%	13%
≥$40K but <$50K	2%	11%
≥$50K	2%	40%
Occupation of breadwinner:		
Agricultural industry	26%	7%
Labor	27%	27%
Sales	3%	14%
Management	6%	11%

[a] Percentages do not always sum to 100% due to lack of responses from various completed questionnaires.
[b] 2007 data from United States Census Bureau: http://factfinder.census.gov.
[c] Data unavailable.

β_js were used to identify subgroups of consumers that exhibited a significantly (i.e., $P \leq 5\%$) higher/lower willingness to buy live pigs from Kentucky producers.

RESULTS

Survey results showed that most of the respondents (74%) bought groceries primarily from chain stores, such as Wal-Mart and Kroger, with only 26% of respondents buying food mainly from smaller grocery chains such as Save-A-Lot and Hispanic groceries. While Hispanic grocery stores were not always the main grocery outlet, they remained popular among Hispanic consumers; 72% of respondents made at least two grocery-shopping trips to Hispanic grocery stores per month. Interestingly, farmers' markets were rarely visited by Hispanic consumers with 69% of respondents reporting that they did not attend farmers' markets; language barrier was the commonly-cited reason for this result.

Respondents indicated their willingness to travel to a farm to buy food items, including live animals. The data showed that 56% of respondents would be willing to travel to a farm to buy food products, and an additional 16% reported that they would also go to farms, except that they did not have transportation. Twenty-four percent of respondents (35 individuals) were willing to travel to farms within a 5 mile radius of their residence, an additional 27% of respondents were willing to travel up to 10 miles of their residence, and an additional 21% were willing to travel to farms that were up to 20 miles of their residence. Correspondingly, 85% of respondents indicated that they would buy food from vendors if they would bring farm products directly to Hispanic communities.

Surveyed consumers indicated their willingness to purchase live pigs. The focus was on live pigs because it is convenient for small-scale producers to sell a few live animals, instead of going to the expense of processing the animals themselves. The data showed that although very few respondents have bought live pigs in Kentucky (4 affirmative responses; 6%), many more were willing to purchase live pigs from Kentucky's producers (42 affirmative responses; 29%). However, proportionately fewer respondents were willing to butcher pigs by themselves; only 19 respondents (13%) were willing to process pigs.

Respondents were asked to indicate their size preferences for live pigs (Table 2). Of the total 50 (35%) respondents who answered with a size preference, more than half (27) preferred pigs between 4.5 kg (10 lbs) and 18 kg (40 lbs). Adult pigs (approximately 45 kg/100 lbs or more) were the next most popular size class with 13 respondents choosing this size.

Respondents indicated how often they would be willing to buy live pigs from farmers. Nineteen respondents (13%) reported they

Table 2. Size of pigs preferred by respondents. N = 144.

Size of pigs	Number of respondents exhibiting preference (percentage)
10 lbs or smaller	6 (4.17%)
>10 and ≤40 lbs	27 (8.75%)
Adult pig	13 (9.03%)
>10 and ≤40 lbs or adult	3 (2.08%)
Any sized live pig	1 (0.69%)

An additional 30% of respondents indicated that they would not purchase live pigs and the remaining 35% of respondents did not respond to this question.

will buy pigs once a year, while an additional 22 respondents (15%) said that they will buy twice per year. Only 6 respondents (4%) said that they will buy live pigs three times, or more, per year.

Statistical analyses investigated if certain consumer characteristics were associated with respondents who exhibited a willingness to buy live pigs. The data showed that 63% of such respondents had spouse and children living with them in Kentucky. This group of respondents, with families living with them, was significantly more willing to buy live pigs (X^2 test statistic, 1 df, was 6.45; P = 1.11%). Respondents who were willing to travel to farms to purchase fresh foods also showed a significantly higher proclivity to buy live pigs (X^2 test statistic, 1 df, was 12.14; P = 0.05%).

Logit regression results corroborated our results above. The dependent variable was binary with a value of 1 indicating that the respondent was willing to buy live pigs; 0, otherwise. Results of this regression that shows that a consumer's willingness to travel to a farm to purchase food, and having their family living with them in Kentucky significantly increased their likelihood of purchasing live pigs (Table 3). However, consumers that spend $500 or more on monthly groceries, on average, had a significantly lower willingness to buy live pigs.

CONCLUSIONS

This study investigated the perceptions of Hispanic consumers towards buying pigs from Kentucky producers. The results showed that there was a strong potential for small-scale pig producers to sell their product to Hispanics. The survey showed that nearly 30% of the respondents were willing to buy live pigs. With the rapid growth of Kentucky's Hispanic population, this represents a substantial demand for such a product.

The main conclusions from this study are 1) consumers willing to travel to farms to buy food products have a significantly higher willingness to buy live pigs, 2) consumers with families in Kentucky also have a significantly higher willingness to buy live pigs, and 3) pigs of size 18 kg (40 lbs) or less are most popular in this market. Additional information from some of the surveyed consumers seemed to indicate that this pig size typically corresponds to the right size for roasting, particularly at family gatherings.

Other results showed that while a sizeable portion of Hispanic consumers were willing to buy live pigs from Kentucky farmers, few were willing to process the animals. This is consistent with findings of Davis and Lin (2005) that suggests that Hispanics would rather purchase whole pig carcasses. This suggests that small-scale pig producers should consider cooperating with local butcher shops such that Hispanic consumers could purchase live pigs from a farm and conveniently have the animals processed to their specifications.

Table 3. Results of a logistic regression on the willingness to buy live pigs by Hispanic consumers in Kentucky to identify systematic effects of demographic parameters[a].

	Regressors[b]					
	Intercept	AgOccup	GoToFarm	FarmToComm	FKY	SpendMore
Coefficient estimate	−4.63	0.33	2.62	0.76	1.08	−2.22
Standard error	1.49	0.49	1.06	1.16	0.54	1.08
P-value (%)	0.19	49.56	1.32	51.19	4.45	4.03

N = 123; Generalized R^2 = 0.21; LR test = 27.36 (P = 0.01%); Tau-a = 0.228.

[a] Dependent variable: BuyLivePigs = 1 if respondents were willing to purchase live pigs from Kentucky producers; '0' otherwise.

[b] AgOccup is a dichotomous variable which is '1' if a respondent had an immediate family member who had an agricultural occupation; '0' otherwise.

GoToFarm is a dichotomous variable which is '1' if a respondent was willing to travel to a farm to purchase food products including live animals; '0' otherwise.

FarmToComm is a dichotomous variable which is '1' if a respondent was willing to support vendors bringing food products from a farm to their community for sale; '0' otherwise.

FKY is a dichotomous variable which is '1' if respondent's spouse and children lived with them in Kentucky; '0' otherwise.

SpendMore = '1' if respondent spent $500 or more, on average, on monthly groceries; otherwise it is '0'.

In conclusion, this paper indicates that there is a direct-to-consumer market where Kentucky farmers could sell pigs to Hispanic consumers, although this sales potential will be fully realized if fresh pig carcasses of size between 4.5 kg (10 lbs) and 18 kg (40 lbs) could be sold through local butchers. The survey data showed that 72% of respondents would travel 20 miles or less from their residence to a farm to buy various food products, including animals. Hence, Kentucky producers within 20 miles of Hispanic population centers should consider diversifying into direct marketing to Hispanic consumers and pigs could be an important part of their various product offerings.

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Effect of Different Schedules of Baby Corn (*Zea mays* L.) Harvests on Baby Corn Yield, Grain Yield, and Economic Return

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ABSTRACT

Baby corn (*Zea mays* L.) consists of unfertilized young ears harvested 2 or 3 days after silk emergence. The present study, conducted in 2009, was the culmination of three successive years of production and evaluation of baby corn at Western Kentucky University Agriculture Research and Education Center (36.93 N, 86.47 E) in Bowling Green, Kentucky. The purpose of this study was to compare the effect of different schemes of harvests on baby corn (BC) yield, grain maize (GM) yield, and estimated economic return. Harvest treatments were 1) no BC harvest, only GM harvest, 2) first harvest as BC, final harvest as GM, 3) first and second harvests as BC, final harvest as GM, and 4) first, second, and third harvests as BC, final harvest as GM. Average BC yields (kg/ha) for Treatments 2, 3, and 4 were 1445.1, 2681.8, and 3437.5; Average GM yields (kg/ha) for Treatments 1, 2, and 3 were 12,522.2, 8226.5, and 1380.9; respectively. Since few grain kernels were found after three BC harvests (Treatment 4), no usable GM yield was produced. BC and GM yields were used for evaluating the economic returns. Results indicated that the descending sequence of treatments for economic returns were Treatments 4, 3, 2, and 1. Although the three BC harvest system (Treatment 4) was the most profitable, if required the most human labor and critical timing of harvests. In Kentucky, BC could be grown as an additional crop or to supplant a limited amount of traditional GM hectarage.

KEY WORDS: Baby corn, specialty crop, vegetable crop corn

INTRODUCTION

Maize (*Zea mays* L.) has been cultivated for centuries as a grain crop and more recently as a vegetable crop, including sweet corn (*Zea mays* var. *saccharata*) and baby corn (Muthukumar et al. 2005; Mahajan et al. 2007). Baby corn is the young, finger-length fresh ear harvested within 2 or 3 days of silk emergence but prior to fertilization (Figure 1) (Almeida et al. 2005; Siliva et al. 2006; Mahajan et al. 2007; Muthukumar et al. 2007; Saha et al. 2007). Baby corn is a vegetable crop that can potentially improve the economic status of farmers (Das et al. 2008). In addition to its sweet, succulent taste, baby corn's nutrient value is comparable to other vegetables such as cauliflower, cabbage, and tomato. Thavaprakaash et al. (2005) and Das et al. (2008) reported that baby corn contained 89.1% moisture, 0.2% fat, 1.9% protein, 8.2% carbohydrate, 0.06% ash, 0.028% calcium, 0.086% phosphorus, and 0.011% ascorbic acid.

Globally, as an immature vegetable, baby corn consumption has increased due to the enhanced living standards and shift in dietary habit from non-vegetarian to vegetarian; however, the production areas are still confined to a few countries, including Thailand, Indonesia, India, and Brazil. The greatest production of baby corn is in Thailand with the value of approximate $64 million (U.S.) in 2000 (Chatuchak 2001). In addition to high nutritional value as human food, another benefit of baby corn consists of utilizing the husk, silk, and stover as green herbage for feeding ruminants and swine (Aekatasanawan 2001). There are no reported data for baby corn production in the United States; nevertheless, the U.S. is the leading importer of baby corn, mainly from Thailand. The U.S. imports accounted for approximately 40% of total baby corn exported by these countries (Aekatasanawan 2001). In the U.S., baby corn production is its infancy and there is a dearth of research information, especially on the impact of baby corn harvest systems on baby corn yield and economic returns; therefore, it is imperative that further research be conducted to improve both yield and quality.

The objective of the present study was to compare the effect of different systems of harvest on baby corn yield, grain yield, and estimated economic return.

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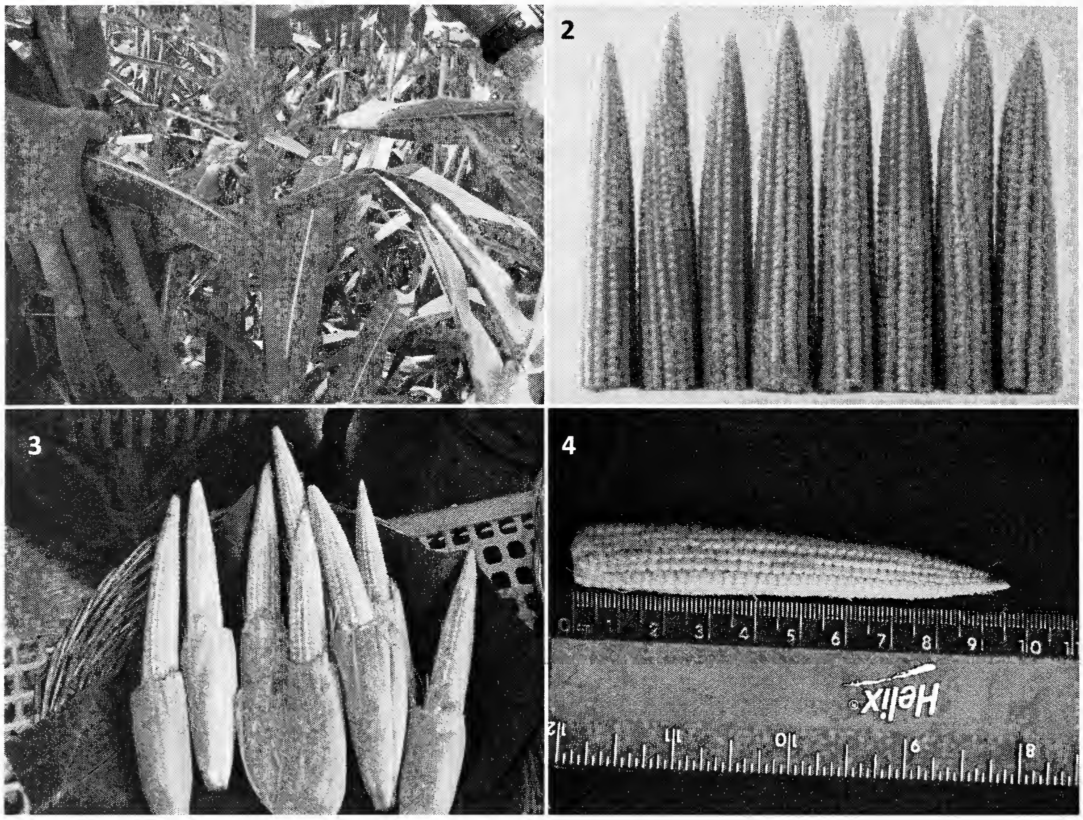


Figure 1. Regular baby corn ears and acceptable baby corn ear (Stone et al. 2008, unpublished).

MATERIALS AND METHODOLOGY

The field study was conducted in 2009 at Western Kentucky University Agriculture Research and Education Center, Bowling Green, Kentucky (36.93 N, 86.47 E). The experiment was a two-way design with four harvest treatments and eight locations as replications. The four treatments included: 1) only harvest as grain, 2) first harvest as baby corn, then as grain, 3) first and second harvests as baby corn and final for grain harvest, and 4) first, second, and third harvests as baby corn, and final for grain. An experimental unit consisted of two rows with 5.33 m in length and separated by 0.76 m. The locations (replications) were on the same farm, separated by a maximum distance of approximately 500 m, and on the same soil, Crider silt loam (*Typic Paleudalf*). Field corn experimental lines being evaluated for production in Central Kentucky were used in the study. The Northrup King lines were '*N77F-3000GT*', '*NCT-3000GT*', '*EXIGEN-518*', and '*N77P-3000GT*', seeded at 62,000 to 70,000 plants per hectare.

Soil test results for eight locations gave ranges of 5.1 to 6.3 for pH; no lime was applied. Nitrogen (N) was applied at 188 kg/ha for all eight locations, phosphorus (P_2O_5) application ranged from 38 to 56 kg/ha, and potassium (k_2O) application ranged from 28 to 38 kg/ha for eight locations. Pre- and post-plant glyphosate applications were used for weed control. Baby corn ears were harvested at weekly intervals, counted, weighed, and categorized into marketable and unmarketable based upon the standard by Aekatasanawan (2001). Weights (g) of the marketable and unmarketable husk covered ears were recorded in order to determine yield (kg/ha). Ears were left in the husk to extend their fresh condition. All baby corn harvests were completed between 8 July and 4 August; all grain harvests were completed between 14 and 17 September when the grain moisture ranged from 30–35%. For each treatment, total

Table 1. Average number of baby corn ears per row from first, second, and third harvests within and across locations.

Order of harvest	Number of ears by location 1	2	3	4	5	6	7	8	Total	Average[1]
First	31	16	15	30	27	18	19	19	175	21.9 A
Second	17	29	23	26	29	25	31	26	206	25.8 A
Third	9	5	12	22	14	12	14	20	108	13.5 B
Total	57	50	50	78	70	55	64	65	489	
Average[2]	19.0	16.7	16.7	26.0	23.3	18.3	21.3	21.7		

[1] DMR-average followed by different letters are significantly different at $P < 0.01$.
[2] Location averages are not significantly different ($P > 0.05$).

number of ears was recorded and three ears were randomly selected and shelled to determine the grain-cob ratio. Total kernel weight was used for estimating the grain yield (kg/ha) at 15% moisture (Hoeft et al. 2000).

For analysis, baby corn income was sourced from the number of harvested marketable ears per hectare with the unit price of 12 ears per dollar. Cost was mainly the labor expense for harvesting and varied by different treatments. Likewise, for grain maize, income was sourced from the unit price of the American Maize Market, $3.35 per bushel, converted to approximately $132 per metric ton. Cost for grain harvest was divided into variable cost (seed, fertilizer, herbicide, pesticide, fuel, machine repairs, and labor) and fixed cost (depreciation, taxes, and insurance). All costs were the same for each treatment because there was only one grain harvest. Net incomes for both baby corn and grain maize were generated by the subtraction of respective costs from the gross income. The final net profit values for each treatment came from the summation of baby corn and grain maize's net incomes.

Analysis of variance was conducted for baby corn yield, number of baby corn ears, and grain yield. Comparisons of the averages over the four treatments and eight locations were analyzed using Duncan Multiple Range Test to further determine the difference among treatments and locations.

RESULTS AND ANALYSES

Number of Baby Corn Ears

Difference among three harvests were highly significant ($P < 0.01$); whereas, locations did not differ ($P > 0.05$). Further comparison indicated that average number of baby corn ears in the third harvest was lower ($P < 0.01$) than first and second harvests which did not differ from one another ($P > 0.05$) (Table 1). Results indicated that removing the first harvest as baby corn stimulated more inflorescences (baby corn ears) in the second harvest. However, the number of baby corn ears for the third harvest was 50% less than the second harvest.

Percentage of Market Acceptable Baby Corn Ears

Percentages of acceptable baby corn ears were determined based upon established standards for marketable baby corn (Aekatasanawan 2001). These requirements include: 1) ear size of 4 to 9 cm length and 1.0 to 1.5 cm diameter, and 2) good quality such as straight ovary row arrangement, unfertilized and unbroken ears, and size within factory specifications (Figure 1). Results showed that the percentages of acceptable ears for harvests 1, 2, and 3 were 96.9, 48.6, and 57.5; respectively. All differences among harvest means were highly significant ($P < 0.01$) (Table 2).

Table 2. Percentage of marketable baby corn ears of first, second, and third harvests within and across locations.

Order of harvest	Marketable ears by location (%) 1	2	3	4	5	6	7	8	Average[1]
First	93.5	100	93.3	93.3	100	100	94.7	100	96.9 A
Second	41.2	27.6	56.5	42.3	48.3	64.0	54.8	53.8	48.6 C
Third	55.6	60.0	41.7	54.5	50.0	66.7	71.4	60.0	57.5 B
Average[2]	63.4	62.5	63.8	63.4	66.1	76.9	73.6	71.3	

[1] DMR-average followed by different letters are significantly different at $P < 0.01$.
[2] Location averages are not significantly different ($P > 0.05$).

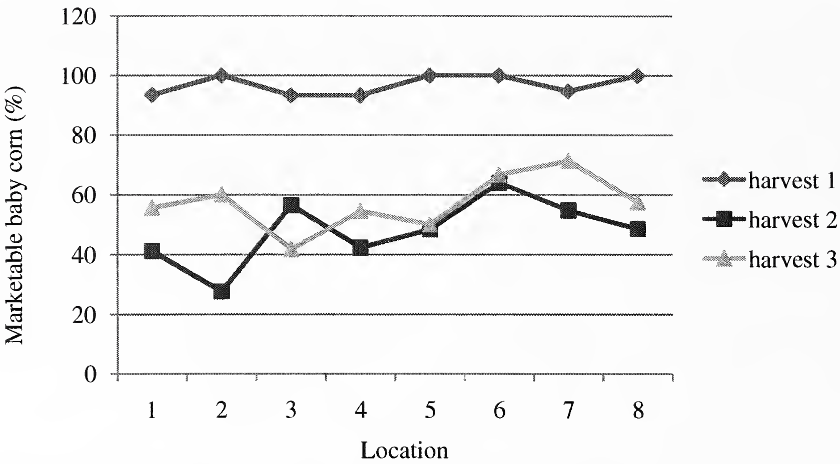


Figure 2. Percentage of marketable baby corn for first, second, and third harvests within each location. BC = Baby corn. GM = Grain maize.

There was no significant difference ($P > 0.05$) in percentages marketable ears among locations (Table 2). Although the average number of harvested baby corn ears was the largest in the second harvest, average percentage of the marketable baby corn ear was the lowest (Table 1, Figure 2). This situation suggests that production and growth of baby corn were accelerated during the period between first and second harvests.

Baby Corn Yield

Baby corn yields for Treatments 2, 3, and 4 were based upon weights of the marketable ears for each treatment. Results showed that Treatment 4 had the largest yield of the three treatments ($P < 0.01$) and that yield increased with the increase in number of baby corn harvests (Treatment 2 to Treatment 4, Table 3). DMR test results showed that differences ($P < 0.01$) existed among the three treatments (Table 3). Number of marketable baby corn ears per hectare was also estimated with the basis of total number of harvested marketable baby corn ears. Similar results were obtained in which Treatment 4 had a greater ($P < 0.01$) number of marketable baby corn ears compared with the other two treatments (Table 4).

Grain Yield

Average grain yield of Treatment 1 which had no baby corn harvest was greater ($P < 0.01$) than those for Treatments 2, 3, and 4 which had baby corn harvests (Table 5). Treatment 2 which had only one baby corn harvest produced more grain than Treatments 3 and 4 which had two and three baby corn harvests; respectively (Table 5). Treatment 4 which had three baby corn harvests produced negligible grain yield.

Combination of Baby Corn and Grain Yield

Combinations of average baby corn yield and grain yield for each treatment are presented in

Table 3. Estimated baby corn yields for Treatments 2, 3, and 4 within and across locations.

	Baby corn yield by locations (kg/ha)								
Treatments	1	2	3	4	5	6	7	8	Treatment average[1]
2	1876.0	1086.8	895.4	2092.1	1977.2	1440.0	1010.2	1183.1	1445.1 C
3	2829.4	2082.2	1936.5	2579.9	3842.1	2431.7	2636.7	3115.9	2681.8 B
4	4513.9	1403.0	3030.7	4770.8	4165.7	2957.8	3835.9	2822.0	3437.5 A
Location average[2]	3073.1 AB	1524.0 D	1954.2 CD	3147.6 AB	3328.3 A	2276.5 C	2494.3 BC	2373.7 C	

[1] DMR-average followed by different letters are significantly different at $P < 0.01$.
[2] DMR-location averages followed by same letters are not significant ($P > 0.01$).

Table 4. Estimated number of baby corn ears per hectare for Treatments 2, 3, and 4 within and across locations.

	Number of baby corn ears by location								
Treatments	1	2	3	4	5	6	7	8	Treatment average[1]
2	61750	43225	34580	82745	67925	45695	49400	41990	53413 C
3	121030	124735	87685	138320	140790	111150	128440	130910	122882 B
4	156845	109915	137085	187720	175370	137085	155610	155610	151905 A
Location average[2]	113208 B	92625 CD	86450 D	136261 A	128028 A	97976 CD	111150 BC	109503 BC	

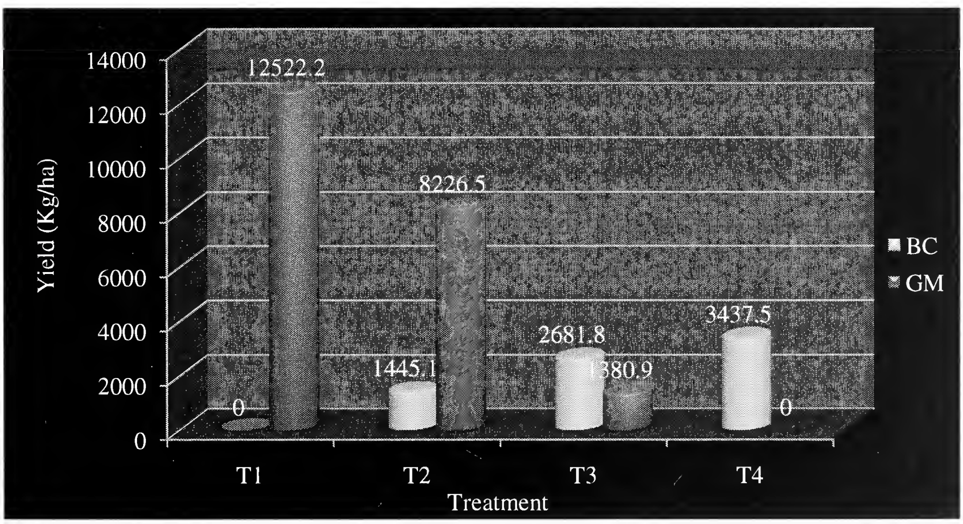
[1] DMR-average followed by different letters are significantly different at $P < 0.01$.
[2] DMR-location averages followed by same letters are not significant ($P > 0.01$).

Table 5. Estimated grain yield for each treatment within and across eight locations.

	Grain yield by locations (kg/ha)								
Treatments	1	2	3	4	5	6	7	8	Treatment average[1]
1	10184.8	13414.6	10327.8	14887.4	15462.9	14236.1	10280.0	11383.6	12522.2 A
2	6484.9	8203.7	10258.9	9270.8	9819.0	6817.4	7230.2	7727.2	8226.5 B
3	447.5	447.9	4109.3	1583.9	1487.1	878.5	740.2	1353.1	1380.9 C
Location average[2]	5705.7	7355.4	8232.0	8580.7	8923.0	7310.7	6083.5	6821.3	

[1] DMR- average followed by different letters are significantly different at $P < 0.01$.
[2] Location averages are not significantly different ($P > 0.05$).

Figure 3. As baby corn yield increased, grain yield decreased markedly from Treatment 1 to 3 and reached 0 in Treatment 4. In Treatment 4, average grain yields for eight locations were less than 50 kg/ha, which were agronomically negligible. Correlation analyses showed that baby corn yield was positively correlated ($r = 0.996$, $P < 0.01$) with number of marketable baby corn ears but negatively correlated ($r = -0.988$, $P < 0.05$) to grain yield and likewise, number of marketable baby corn ears was negatively correlated ($r = -0.997$, $P < 0.01$) with grain yield, resulting in a substantially negative relationship between grain yield and



BC=Baby corn

GM=Grain maize

Figure 3. Average baby corn and grain yields for the four treatments.

Table 6. Average net economic returns ($) per hectare for different schedules of maize harvests across eight locations.

	Economic return for the four treatments ($)			
	1	2	3	4
Baby corn incomes	0	4451	10240	12658
Baby corn cost	0	1853	3706	5559
Net income of baby corn	0	2598	6534	7099
Grain income	1652	1085	182	0
Grain production cost				
Variable cost	539	539	539	539
Fixed cost	123	123	123	123
Total grain production cost	662	662	662	662
Net income of grain production	990	423	−480	−662
Total net income	990	3021	6054	6437

baby corn yield and with number of marketable baby corn ears.

Economic Return

The economic returns for different harvest models were variable. For baby corn, it was estimated that 247 hours would be needed per hectare with a cost of $7.50 per hour, resulting in the total labor cost as $1853 per hectare for each harvest. Based upon a standard price of baby corn ear ($1 per dozen), estimated income of marketable baby corn ears for Treatments 2, 3, and 4 were $4451, $10,240, and $12,658; respectively. Labor costs for Treatments 2, 3, and 4 were $1853, $3706, and $5559; respectively. Thus, net returns per hectare for baby corn under diverse harvests (4 treatments) from eight locations were 0, $2598, $6534, and $7099; respectively. For grain harvest, average incomes per hectare for grain under different treatments through the eight locations were $1652, $1085, $182, $0 (no usable grain harvest); respectively (Tables 5, 6). Based upon University of Kentucky Agricultural Extension's report, the total variable and fixed costs for grain production per hectare were estimated as $539 and $123 with total cost of $662 (Table 6). Average net incomes for different treatments among locations were $990, $423, $-480, and $-662 per hectare; respectively (Table 6). Hence, total net returns per hectare for Treatments 1, 2, 3, and 4 were $990, $3021, $6054, and $6437; respectively (Table 6).

DISCUSSION AND SUMMARY

Corn plants have a high level of plasticity for number of ear shoots per plant. In grain production most plants produce a maximum of two shoots. However, early removal of an ear shoot often results in another shoot emergence from the next lower leaf axil. This characteristic of corn plants is basic to baby corn, a specialty corn industry that is well established in Asia but only of recent recognition in the United States.

Figure 4. Baby corn ear shoots at low leaf axil and brace root.

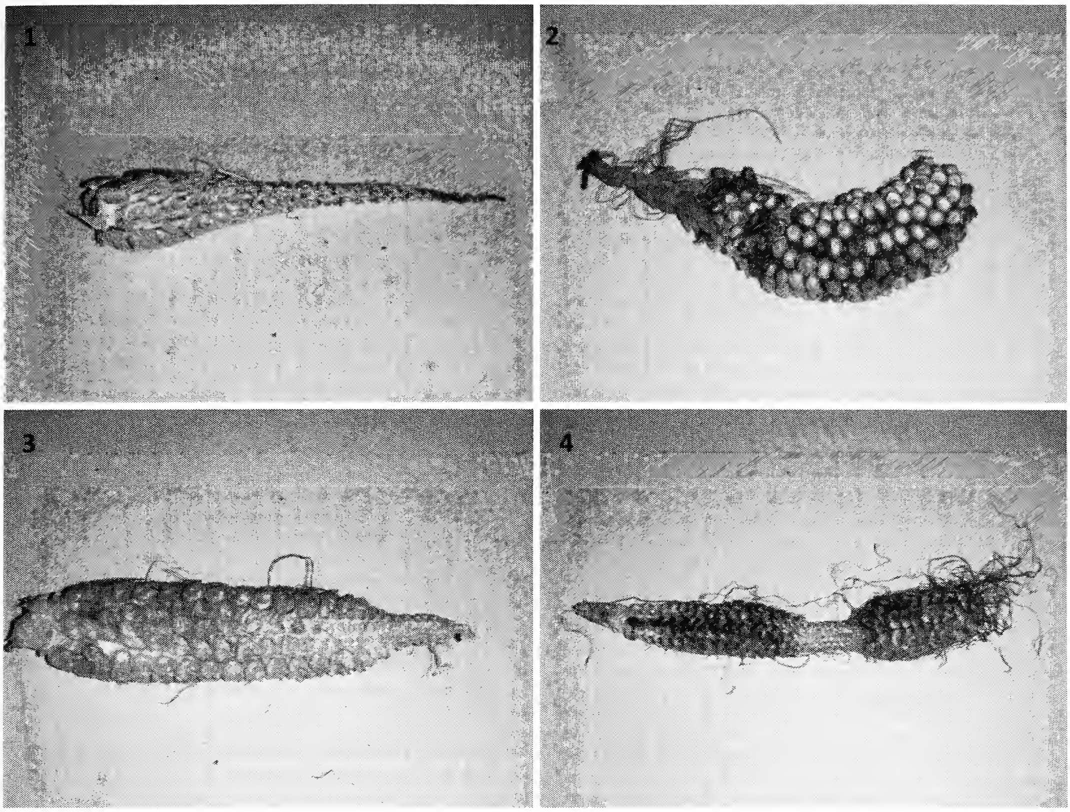


Figure 5. Bare cobs after three harvests as baby corn selected from plants in Treatment 4.

A tripartite set of questions were pursued in the present study. First, will plants continue to produce both quantity and quality baby corn over successive harvests? The results indicated that at least three baby corn harvests at weekly intervals were productive. The seven-day harvest interval was too long resulting in ears that often exceeded market standard for length and width. It was apparent that three-day harvest intervals as reported by Silva et al. (2006) would increase the number of acceptable ears. Although quality as indicated by ear shape, size, and straightness of ovary arrangement, deteriorated with successive harvests, some plants were observed that produced ears shoots at their base even below brace roots (Figure 4).

Second, will harvests of baby corn impact the subsequent grain yield in the present study? Baby corn was not harvested in Treatment 1, providing the control for the other treatments which were harvested for baby corn. In all comparisons, subsequent grain production was reduced by previous baby corn harvest(s). Compared with Treatment 1, reductions for 1, 2, and 3 harvests (Treatments 2, 3, and 4) were 34%, 89%, and 100%; respectively. Three harvests of baby corn over a two-week period (Treatment 4) resulted in virtual failure of grain production. The plants continued to produce cobs and ovules but few or no grains indicating cessation of pollen production (Figure 5). Others, including Geraldi et al. (1985), Almeida et al. (2005), and Silva et al. (2006), reported that corn produced pollen for 7 to 9 days. Ears left for subsequent grain production would need to be pollinated within this period.

Third, what will be the likely economic impact of the negative association between baby corn and grain yield? Income figures in Table 6 showed the increase in income from baby corn and the decrease from grain production as the number of baby corn harvests increased within each treatment, resulting in an increased total net income. The explanation would be that increased time for additional baby corn harvest

shortened the period of pollen availability for grain production. These results indicated that the lowest income resulted from only grain harvest and highest income from only baby corn harvest. It would be advantageous for larger corn producers to meet expected market demands by taking a small area and harvesting only baby corn multiple times rather than using a larger area and harvesting fewer times. Shortening harvest intervals to three days would increase the percentage of marketable baby corn ears. In combined production, earlier final baby corn harvest is conducive to more completed fertilization of ovules for final grain harvest.

In the present study, there were no consistent differences among locations or cultivars. However, there was only limited variation within each of these factors. It is not expected that baby corn production will be restricted by cultivars or environments. The three critical factors for baby corn production are timing of harvest, intensity of harvesting labor, and available markets.

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Rare and Extirpated Biota and Natural Communities of Kentucky

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ABSTRACT
The Kentucky State Nature Preserves Commission has updated and revised the lists of rare and extinct or extirpated biota last published in 2000 and updated in 2001, 2004 and 2005 based on a standard methodology now utilized by NatureServe. Natural communities have been included in this update. The newly revised lists include one lichen, 387 vascular plant and lesser taxa, 346 animal taxa, and 36 natural communities considered rare. Nineteen plant and 47 animal taxa are considered extirpated or extinct from Kentucky.
KEY WORDS: Threatened, endangered, extinct, status, rare species, natural communities, Kentucky

INTRODUCTION

The Kentucky State Nature Preserves Commission (KSNPC) is mandated to identify and protect natural areas to conserve Kentucky's natural heritage. To accomplish this mandate, KSNPC works in cooperation with many scientific authorities in the public, private, and academic sectors. KSNPC uses the Natural Heritage Program (NHP) information system (NatureServe 2010a) to manage distributional and ecological information on rare taxa, high quality natural communities, and other unique natural features. This information is used to assess conservation status and priorities through the evaluation of occurrences of rare taxa, communities, and their supporting natural environments.

Utilizing this methodology, KSNPC has developed a list of taxa and communities native to the state that are considered rare. In addition, a list of species presumed extinct or extirpated from Kentucky is maintained to document losses of biodiversity, much of which are attributable to human activities. The overall goal of publishing these lists is to assist in the recovery and preservation of Kentucky's rich natural diversity and to disseminate conservation status information to interested parties. KSNPC has utilized the NHP methodology for previous iterations of this list.

Abernathy et al. (2010) recently published a list of Kentucky's species and natural communities. While Abernathy et al. (2010) was based on 2007 data; this paper provides the most currently available information. It differs both in terms of the number of species listed as rare and has several adjusted conservation ranks. Furthermore, this marks the first iteration of rare, threatened, and endangered natural communities. We intend this list to be of use to academic and other scientific professionals.

MATERIALS AND METHODS

Each taxon or community listed by KSNPC (most recently in 2000, 2001, 2004, 2005), as well as other unlisted organisms or communities, was evaluated to assign a conservation status. Evaluation criteria used included the number, age, quality, and accuracy of element occurrences, historical and present geographic distributions, habitat requirements, threats to the taxon or community including habitat loss, and ecological sensitivity. The information used to make the evaluation was available as of 30 November 2010. The resulting list and proposed status designations were submitted to state and regional experts for peer review; their recommendations were used to refine the list and rankings. All comments received were considered and in many cases discussed with the reviewer before the list was finalized.

Sources consulted for the plant and lichen names were Anderson (1990), Jones (2005), and Esslinger (2009). Sources consulted for the common and scientific names of animals were as follows: gastropods - Hubricht (1985), Turgeon et al. (1998), and Minton and Lydeard (2003); freshwater mussels - Gordon (1995) and Turgeon et al. (1998); crustaceans - Barr (1968), Holsinger (1972), Hobbs (1989), Zhang and Holsinger (2003), Taylor and Schuster (2004), McLaughlin et al. (2005),

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Taylor et al. (2007), and Buhay and Crandall (2008); insects – Hodges (1983), Barr (1996; 2004), McCafferty (1996), Stark et al. (1998), Needham et al. (2000), Westfall and May (2006), Pelham (2008), NatureServe (2010a), and Morse (2010); fishes - Page and Burr (1991), Nelson et al. (2004), Blanton and Jenkins (2008), Welsh and Wood (2008), Strange and Mayden (2009), and USFWS (2010a); amphibians and reptiles - King and Burke (1989), Collins and Taggart (2002), and Crother (2008); breeding birds - AOU (1998); mammals - Hall (1981), Jones et al. (1992), and Wilson and Reeder (1993).

Because no standard nomenclature exists for natural communities in Kentucky, KSNPC has developed a working classification (KSNPC 2009) that has resulted in a non-standard set of names. Sources consulted were specific to Kentucky, surrounding states, or the overall region and focused on vegetation ecology and/or natural community classification. Synoptic sources for the current KSNPC classification include Braun (1935, 1950), Cowardin et al. (1979), KSNPC (1991, 2009), Fleming et al. (2006), Grossman et al. (1998), Nelson (2007), and NatureServe (2010b).

Status Designations

The intent of assigning status designations was to (1) indicate the degree of rarity of the taxon or community, (2) indicate the degree of threat to the continued survival of the taxon or community, and (3) aid in establishing conservation priorities. The five KSNPC status designations defined below have no legal or statutory implication.

Endangered (E). A taxon or natural community in danger of extirpation and/or extinction throughout all or a significant part of its range in Kentucky.

Threatened (T). A taxon or natural community likely to become endangered within the foreseeable future throughout all or a significant part of its range in Kentucky.

Special Concern (S). A taxon or natural community that should be monitored because (1) it exists in a limited geographic area in Kentucky, (2) it may become threatened or endangered due to modification or destruction of habitat, (3) certain characteristics or requirements make it especially vulnerable to specific pressures, (4) experienced researchers have identified other factors that may jeopardize it, or (5) it is thought to be rare or declining in Kentucky, but insufficient information exists for assignment to the threatened or endangered status categories.

Historical (H). A taxon or natural community that has not been reliably reported in Kentucky since 1990 but is not considered extinct or extirpated—see next designation.

Extinct/Extirpated. A taxon for which habitat loss has been pervasive and/or concerted efforts by knowledgeable biologists to collect or observe specimens within appropriate habitat have failed.

Federal statuses are defined below. Non-breeding birds with a federal status occurring as a migrant or visitor in Kentucky (e.g., *Charadrius melodus*, *Mycteria americana*) are not included within this list (Note, no natural communities have been assigned a federal status).

Endangered (E). "… any species … in danger of extinction throughout all or a significant portion of its range …" (USFWS 2010a).

Threatened (T). "… any species … likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (USFWS 2010a).

Candidate (C). Taxa for which the USFWS has "… sufficient information on biological status and threats to propose them as endangered or threatened" (USFWS 2010b).

RESULTS

Our analysis designates one lichen, 387 vascular plant and lesser taxa, 346 animal taxa, and 36 natural communities as rare in Kentucky (Tables 1, 2). Based on generally accepted estimates of the number of native taxa in Kentucky and the KSNPC estimate of the number of natural communities (not including extirpated or extinct), the following approximate percent of the groups are considered to be Endangered, Threatened, Special Concern, or Historical. The numbers of respective Kentucky native species/communities are given in parentheses.

- Vascular plant species and lesser taxa (2,347, unknown for lichens): 16.4%
- Gastropods (251): 10.7%
- Freshwater mussels (103): 33%
- Crustaceans (unknown): unknown

Table 1. Kentucky's endangered, threatened, special concern, and historical biota and natural communities, 2010.

	Status	
	KSNPC	U.S.
Lichens		
Phaeophyscia leana Lea's Bog Lichen	E	—
Plants		
Mosses[1]		
Abietinella abietina Wire Fern Moss	T	—
Anomodon rugelii	T	—
Brachythecium populeum Matted Feather Moss	E	—
Bryum cyclophyllum	E	—
Bryum miniatum	E	—
Cirriphyllum piliferum	T	—
Dicranodontium asperulum	E	—
Entodon brevisetus	E	—
Herzogiella turfacea	E	—
Neckera pennata	T	—
Oncophorus raui	E	—
Orthotrichum diaphanum	E	—
Polytrichum pallidisetum A Hair Cap Moss	T	—
Polytrichum piliferum	E	—
Polytrichum strictum	E	—
Sphagnum quinquefarium A Sphagnum Moss	E	—
Tortula norvegica Tortula	E	—
Vascular Plants		
Acer spicatum Mountain Maple	E	—
Aconitum uncinatum Blue Monkshood	T	—
Adiantum capillus-veneris Southern Maidenhair-fern	T	—
Adlumia fungosa Allegheny-vine	H	—
Aesculus pavia Red Buckeye	T	—
Agalinis auriculata Earleaf False Foxglove	E	—
Agalinis obtusifolia Ten-lobe False Foxglove	E	—
Agalinis skinneriana Pale False Foxglove	H	—
Ageratina luciae-brauniae Lucy Braun's White Snakeroot	S	—
Agrimonia gryposepala Tall Hairy Groovebur	T	—
Amianthium muscitoxicum Fly Poison	E	—
Amsonia tabernaemontana var. *gattingeri* Eastern Blue-star	E	—
Angelica atropurpurea Great Angelica	E	—
Angelica triquinata Filmy Angelica	E	—
Apios priceana Price's Potato-bean	E	LT
Arabis hirsuta Western Hairy Rockcress	H	—
Arabis missouriensis Missouri Rockcress	H	—
Arabis perstellata Braun's Rockcress	T	LE
Aralia nudicaulis Wild Sarsaparilla	E	—
Aristida ramosissima Branched Three-awn Grass	H	—
Armoracia lacustris Lakecress	T	—
Aureolaria patula Spreading False Foxglove	S	—
Baptisia australis var. *minor* Blue Wild Indigo	S	—
Baptisia bracteata var. *glabrescens* Cream Wild Indigo	S	—
Baptisia tinctoria Yellow Wild Indigo	T	—
Bartonia virginica Yellow Screwstem	T	—
Berberis canadensis American Barberry	E	—
Berchemia scandens Supple-jack	T	—
Bolboschoenus fluviatilis River Bulrush	E	—

Table 1. Continued.

	Status	
	KSNPC	U.S.
Botrychium matricariifolium Matricary Grape-fern	E	—
Botrychium oneidense Blunt-lobe Grape-fern	H	—
Bouteloua curtipendula Side-oats Grama	S	—
Boykinia aconitifolia Brook Saxifrage	E	—
Cabomba caroliniana Carolina Fanwort	T	—
Calamagrostis canadensis var. *macouniana* Blue-joint Reedgrass	H	—
Calamagrostis porteri ssp. *insperata* Bent Reedgrass	E	—
Calamagrostis porteri ssp. *porteri* Porter's Reedgrass	T	—
Calamovilfa arcuata Cumberland sandgrass	E	—
Calopogon tuberosus Grass Pink	E	—
Calycanthus floridus var. *glaucus* Eastern Sweetshrub	T	—
Calylophus serrulatus Yellow Evening Primrose	H	—
Carex aestivalis Summer Sedge	E	—
Carex alata Broadwing Sedge	T	—
Carex appalachica Appalachian Sedge	T	—
Carex atlantica ssp. *capillacea* Prickly Bog Sedge	E	—
Carex austrocaroliniana Tarheel Sedge	S	—
Carex buxbaumii Brown Bog Sedge	H	—
Carex comosa Bristly Sedge	H	—
Carex crawei Crawe's Sedge	S	—
Carex crebriflora Coastal Plain Sedge	E	—
Carex decomposita Epiphytic Sedge	T	—
Carex gigantea Large Sedge	E	—
Carex hystericina Porcupine Sedge	H	—
Carex joorii Cypress-swamp Sedge	E	—
Carex juniperorum Juniper Sedge	E	—
Carex leptonervia Finely-nerved Sedge	E	—
Carex pellita Woolly Sedge	H	—
Carex reniformis Reniform Sedge	E	—
Carex roanensis Roan Mountain Sedge	E	—
Carex seorsa Weak Stellate Sedge	T	—
Carex stipata var. *maxima* Stalkgrain Sedge	H	—
Carex straminea Straw Sedge	T	—
Carex tetanica Rigid Sedge	E	—
Carex tonsa var. *rugosperma* Umbel-like Sedge	T	—
Carya aquatica Water Hickory	T	—
Castanea dentata American Chestnut	E	—
Castanea pumila Allegheny Chinkapin	T	—
Castilleja coccinea Scarlet Indian Paintbrush	E	—
Cayaponia quinqueloba Five-lobe Cucumber	E	—
Ceanothus herbaceus Prairie Redroot	T	—
Cheilanthes alabamensis Alabama Lipfern	H	—
Cheilanthes feei Fee's Lipfern	E	—
Chelone obliqua var. *obliqua* Red Turtlehead	E	—
Chelone obliqua var. *speciosa* Rose Turtlehead	S	—
Chrysogonum virginianum Green-and-gold	E	—
Chrysosplenium americanum American Golden-saxifrage	T	—
Cimicifuga rubifolia Appalachian Bugbane	T	—
Circaea alpina Small Enchanter's Nightshade	S	—
Clematis catesbyana Satin-curls	H	—
Clematis crispa Blue Jasmine Leather-flower	T	—

Table 1. Continued.

	Status KSNPC	U.S.
Collinsonia verticillata Whorled Horse-balm	E	—
Collinsonia verticillata Whorled Horse-balm	E	—
Conradina verticillata Cumberland Rosemary	E	LT
Convallaria montana American Lily-of-the-valley	E	—
Corallorhiza maculata Spotted Coralroot	E	—
Coreopsis pubescens Star Tickseed	S	—
Corydalis sempervirens Rock Harlequin	S	—
Cymophyllus fraserianus Fraser's Sedge	E	—
Cyperus plukenetii Plukenet's Cyperus	H	—
Cypripedium candidum Small White Lady's-slipper	E	—
Cypripedium kentuckiense Kentucky Lady's-slipper	E	—
Cypripedium parviflorum Small Yellow Lady's-slipper	T	—
Dalea purpurea Purple Prairie-clover	S	—
Delphinium carolinianum Carolina Larkspur	T	—
Deschampsia cespitosa Tufted Hairgrass	E	—
Deschampsia flexuosa Crinkled Hairgrass	T	—
Dichanthelium boreale Northern Witchgrass	S	—
Didiplis diandra Water-purslane	E	—
Dodecatheon frenchii French's Shooting Star	S	—
Draba cuneifolia Wedge-leaf Whitlow-grass	E	—
Drosera brevifolia Dwarf Sundew	E	—
Drosera intermedia Spoon-leaved Sundew	E	—
Dryopteris carthusiana Spinulose Wood Fern	S	—
Echinodorus berteroi Burhead	T	—
Echinodorus tenellus var. *parvulus* Dwarf Burhead	E	—
Eleocharis flavescens Bright Green Spikerush	S	—
Elodea nuttallii Western Waterweed	T	—
Elymus svensonii Svenson's Wildrye	T	—
Eriophorum virginicum Tawny Cotton-grass	E	—
Eryngium integrifolium Blue-flower Coyote-thistle	E	—
Erythronium rostratum Yellow Troutlily	S	—
Eupatorium maculatum Spotted Joe-pye-weed	H	—
Eupatorium semiserratum Small-flower Thoroughwort	E	—
Eupatorium steelei Steele's Joe-pye-weed	T	—
Euphorbia mercurialina Mercury Spurge	T	—
Eurybia hemispherica Tennessee Aster	E	—
Eurybia radula Rough-leaved Aster	E	—
Eurybia saxicastellii Rockcastle Aster	T	—
Fimbristylis puberula chesnut sedge	T	—
Forestiera ligustrina Upland Privet	T	—
Gaylussacia ursina Bear huckleberry	T	—
Gentiana decora Showy Gentian	S	—
Gentiana flavida Yellow Gentian	E	—
Gentiana puberulenta Prairie Gentian	E	—
Gleditsia aquatica Water Locust	S	—
Glyceria acutiflora Sharp-scaled Manna-grass	E	—
Goodyera repens Lesser rattlesnake-plantain	E	—
Gratiola pilosa Shaggy Hedgehyssop	T	—
Gratiola quartermaniae Quarterman's Hedge-hyssop	H	—
Gratiola viscidula Short's Hedgehyssop	S	—
Gymnopogon ambiguus Bearded Skeleton-grass	S	—

Table 1. Continued.

	Status KSNPC	U.S.
Gymnopogon brevifolius Shortleaf Skeleton-grass	E	—
Halesia carolina Common Silverbell	E	—
Hedeoma hispidum Rough Pennyroyal	T	—
Helianthemum bicknellii Plains Frostweed	E	—
Helianthemum canadense Canada Frostweed	E	—
Helianthus eggertii Eggert's Sunflower	T	—
Helianthus silphioides Silphium Sunflower	E	—
Heracleum lanatum Cow-parsnip	H	—
Heteranthera dubia Grassleaf Mud-plantain	S	—
Heteranthera limosa Blue Mud-plantain	S	—
Heterotheca subaxillaris var. *latifolia* Broad-leaf Golden-aster	T	—
Hexastylis contracta Southern Heartleaf	E	—
Hieracium longipilum Hairy Hawkweed	T	—
Houstonia serpyllifolia Michaux's Bluets	E	—
Hydrocotyle americana American Water-pennywort	E	—
Hydrocotyle ranunculoides Floating Pennywort	E	—
Hydrolea ovata Ovate Fiddleleaf	E	—
Hydrolea uniflora One-flower Fiddleleaf	E	—
Hydrophyllum virginianum Eastern Waterleaf	T	—
Hypericum adpressum Creeping St. John's-wort	H	—
Hypericum crux-andreae St. Peter's-wort	T	—
Hypericum pseudomaculatum Large Spotted St. John's-wort	H	—
Iris brevicaulis Zigzag Iris	T	—
Iris fulva Copper Iris	E	—
Isoetes butleri Butler's Quillwort	E	—
Isoetes melanopoda Blackfoot Quillwort	E	—
Juglans cinerea White Walnut	T	—
Juncus articulatus Jointed Rush	S	—
Juncus elliottii Bog Rush	H	—
Juncus filipendulus Ringseed Rush	T	—
Juniperus communis var. *depressa* Ground Juniper	T	—
Koeleria macrantha Prairie Junegrass	E	—
Krigia occidentalis Western Dwarf Dandelion	E	—
Lathyrus palustris Vetchling Peavine	T	—
Lathyrus venosus Smooth Veiny Peavine	S	—
Leavenworthia exigua var. *laciniata* Kentucky Gladecress	E	C
Leavenworthia torulosa Necklace Gladecress	T	—
Lespedeza capitata Round-head Bush-clover	S	—
Lespedeza stuevei Tall Bush-clover	T	—
Lesquerella globosa Globe Bladderpod	E	C
Lesquerella lescurii Lescur's Bladderpod	H	—
Leucothoe recurva Red-twig Doghobble	E	—
Liatris cylindracea Slender Blazingstar	T	—
Lilium philadelphicum Wood Lily	T	—
Lilium superbum Turk's Cap Lily	T	—
Limnobium spongia American Frog's-bit	T	—
Liparis loeselii Loesel's Twayblade	T	—
Listera australis Southern Twayblade	H	—
Listera smallii Kidney-leaf Twayblade	T	—
Lobelia gattingeri Gattinger's Lobelia	E	—
Lobelia nuttallii Nuttall's Lobelia	T	—

Table 1. Continued.

	Status	
	KSNPC	U.S.
Lonicera dioica var. *orientalis* Wild Honeysuckle	E	—
Lonicera reticulata Grape Honeysuckle	T	—
Ludwigia hirtella Hairy Ludwigia	E	—
Lycopodiella appressa Southern Bog Clubmoss	E	—
Lycopodiella inundata Northern Bog Clubmoss	E	—
Lycopodium clavatum Running Pine	E	—
Lysimachia terrestris Swamp Candles	E	—
Magnolia pyramidata Pyramid Magnolia	H	—
Maianthemum canadense Wild Lily-of-the-valley	T	—
Maianthemum stellatum Starflower False Solomon's-seal	E	—
Malus ioensis Iowa Crabapple	S	—
Malvastrum hispidum Hispid Falsemallow	T	—
Marshallia grandiflora Barbara's Buttons	E	—
Matelea carolinensis Carolina Anglepod	E	—
Melampyrum lineare var. *latifolium* American Cowwheat	T	—
Melampyrum lineare var. *pectinatum* American Cow-wheat	H	—
Melanthera nivea Snow Squarestem	S	—
Melanthium virginicum Virginia Bunchflower	E	—
Minuartia cumberlandensis Cumberland Sandwort	E	LE
Minuartia glabra Appalachian Sandwort	T	—
Mirabilis albida Pale Umbrella-wort	H	—
Monotropsis odorata Sweet Pinesap	T	—
Muhlenbergia bushii Bush's Muhly	E	—
Muhlenbergia cuspidata Plains Muhly	T	—
Muhlenbergia glabrifloris Hair Grass	S	—
Myriophyllum heterophyllum Broadleaf Water-milfoil	S	—
Myriophyllum pinnatum Cutleaf Water-milfoil	H	—
Najas gracillima Thread-like Naiad	S	—
Nemophila aphylla Small-flower Baby-blue-eyes	T	—
Nestronia umbellula Conjurer's-nut	E	—
Oclemena acuminata Whorled Aster	T	—
Oenothera linifolia Thread-leaf Sundrops	E	—
Oenothera oakesiana Evening Primrose	H	—
Oenothera perennis Small Sundrops	E	—
Oenothera triloba Stemless Evening-primrose	T	—
Oldenlandia uniflora Clustered Bluets	E	—
Onosmodium hispidissimum Hairy False Gromwell	E	—
Onosmodium molle Soft-hairy False-gromwell	H	—
Onosmodium occidentale Western False Gromwell	E	—
Orobanche ludoviciana Louisiana Broomrape	H	—
Orontium aquaticum Golden Club	T	—
Oxalis macrantha Price's Yellow Wood Sorrel	H	—
Parnassia asarifolia Kidneyleaf Grass-of-parnassus	E	—
Parnassia grandifolia Large-leaved Grass-of-parnassus	E	—
Paronychia argyrocoma Silverling	E	—

Table 1. Continued.

	Status	
	KSNPC	U.S.
Paspalum boscianum Bull Paspalum	S	—
Paxistima canbyi Canby's Mountain-lover	T	—
Perideridia americana Eastern Yampah	T	—
Phacelia ranunculacea Blue Scorpion-weed	S	—
Philadelphus inodorus Mock Orange	T	—
Philadelphus pubescens Hoary Mock Orange	E	—
Phlox bifida ssp. *bifida* Cleft Phlox	T	—
Phlox bifida ssp. *stellaria* Starry-cleft Phlox	E	—
Platanthera cristata Yellow-crested Orchid	T	—
Platanthera integrilabia White Fringeless Orchid	E	C
Platanthera psycodes Small Purple-fringed Orchid	E	—
Poa saltuensis Drooping Bluegrass	E	—
Podostemum ceratophyllum Threadfoot	S	—
Pogonia ophioglossoides Rose Pogonia	E	—
Polygala cruciata Crossleaf Milkwort	E	—
Polygala nuttallii Nuttall's Milkwort	H	—
Polygala paucifolia Gaywings	E	—
Polygala polygama Racemed Milkwort	T	—
Polymnia laevigata Tennessee Leafcup	E	—
Pontederia cordata Pickerel-weed	T	—
Potamogeton amplifolius Large-leaf Pondweed	E	—
Potamogeton illinoensis Illinois Pondweed	S	—
Potamogeton pulcher Spotted Pondweed	T	—
Prenanthes alba White Rattlesnake-root	E	—
Prenanthes aspera Rough Rattlesnake-root	E	—
Prenanthes barbata Barbed Rattlesnake-root	E	—
Prenanthes crepidinea Nodding Rattlesnake-root	S	—
Prenanthes racemosa Glaucous Rattlesnake-root	S	—
Prosartes maculata Nodding Mandarin	S	—
Pseudognaphalium helleri ssp. *micradenium* Small Rabbit-tobacco	H	—
Psoralidium tenuiflorum Few-flowered Scurf-pea	H	—
Ptilimnium capillaceum Mock Bishop's-weed	T	—
Ptilimnium costatum Eastern Mock Bishop's-weed	H	—
Ptilimnium nuttallii Nuttall's Mock Bishop's-weed	E	—
Pycnanthemum albescens Whiteleaf Mountainmint	H	—
Pycnanthemum muticum Blunt Mountainmint	E	—
Quercus ilicifolia Scrub oak	H	—
Quercus nigra Water Oak	T	—
Quercus texana Nuttall's Oak	T	—
Ranunculus ambigens Waterplantain Spearwort	S	—
Rhododendron canescens Hoary Azalea	E	—
Rhynchosia tomentosa Hairy Snoutbean	E	—
Rhynchospora macrostachya Tall Beaked-rush	E	—
Rhynchospora recognita Globe Beaked-rush	S	—
Ribes americanum Eastern Black Currant	T	—
Rubus canadensis Smooth Blackberry	E	—
Rudbeckia subtomentosa Sweet Coneflower	E	—
Sabatia campanulata Slender Marsh Pink	E	—
Sagina fontinalis Water Stitchwort	E	—
Sagittaria graminea Grassleaf Arrowhead	T	—

Table 1. Continued.

	Status KSNPC	U.S.
Sagittaria platyphylla Delta Arrowhead	E	—
Sagittaria rigida Sessile-fruited Arrowhead	E	—
Salix amygdaloides Peach-leaved Willow	H	—
Salix discolor Pussy Willow	H	—
Salvia urticifolia Nettle-leaf Sage	E	—
Sambucus racemosa ssp. *pubens* Red Elderberry	E	—
Sanguisorba canadensis Canada Burnet	E	—
Saxifraga michauxii Michaux's Saxifrage	T	—
Saxifraga micranthidifolia Lettuce-leaf Saxifrage	E	—
Schisandra glabra Bay Starvine	E	—
Schizachne purpurascens Purple Oat	T	—
Schoenoplectus hallii Hall's Bulrush	E	—
Schoenoplectus heterochaetus Slender Bulrush	H	—
Schwalbea americana Chaffseed	H	LE
Scirpus expansus Woodland Beakrush	E	—
Scleria ciliata Fringed Nutrush	E	—
Scutellaria arguta Hairy Skullcap	E	—
Scutellaria saxatilis Rock Skullcap	T	—
Sedum telephioides Allegheny Stonecrop	T	—
Sida hermaphrodita Virginia Mallow	T	—
Silene ovata Ovate Catchfly	E	—
Silene regia Royal Catchfly	E	—
Silphium laciniatum Compassplant	T	—
Silphium pinnatifidum Tansy Rosinweed	S	—
Silphium wasiotense Appalachian Rosinweed	S	—
Solidago albopilosa White-haired Goldenrod	T	LT
Solidago buckleyi Buckley's Goldenrod	S	—
Solidago curtisii Curtis' Goldenrod	S	—
Solidago gracillima Southern Bog Goldenrod	S	—
Solidago puberula Downy Goldenrod	S	—
Solidago roanensis Roan Mountain Goldenrod	T	—
Solidago shortii Short's Goldenrod	E	LE
Solidago simplex ssp. *randii* var. *racemosa* Rand's Goldenrod	S	—
Solidago squarrosa Squarrose Goldenrod	H	—
Sparganium eurycarpum Large Bur-reed	E	—
Sphenopholis pensylvanica Swamp Wedgescale	S	—
Spiraea alba Narrow-leaved Meadow-sweet	H	—
Spiraea virginiana Virginia Spiraea	T	LT
Spiranthes lucida Shining Ladies'-tresses	T	—
Spiranthes magnicamporum Great Plains Ladies'-tresses	T	—
Spiranthes ochroleuca Yellow Nodding Ladies'-tresses	T	—
Spiranthes odorata Sweetscent Ladies'-tresses	E	—
Sporobolus clandestinus Rough Dropseed	T	—
Sporobolus heterolepis Northern Dropseed	E	—
Stachys eplingii Epling's Hedgenettle	H	—
Stellaria longifolia Longleaf Stitchwort	S	—
Stenanthium gramineum Eastern Featherbells	T	—
Streptopus lanceolatus Rosy Twisted-stalk	E	—
Styrax grandifolius Bigleaf Snowbell	E	—
Symphoricarpos albus Snowberry	E	—
Symphyotrichum concolor Eastern Silvery Aster	T	—
Symphyotrichum drummondii var. *texanum* Hairy Heart-leaved Aster	H	—

Table 1. Continued.

	Status KSNPC	U.S.
Symphyotrichum pratense Barrens Silky Aster	S	—
Symphyotrichum priceae White Heath Aster	E	—
Talinum calcaricum Limestone Fameflower	E	—
Talinum teretifolium Roundleaf Fameflower	E	—
Taxus canadensis Canadian Yew	T	—
Tephrosia spicata Spiked Hoary-pea	E	—
Thaspium pinnatifidum Cutleaf Meadow-parsnip	T	—
Thermopsis mollis Soft-haired Thermopsis	E	—
Thuja occidentalis Northern White Cedar	T	—
Torreyochloa pallida Pale Manna Grass	H	—
Toxicodendron vernix Poison Sumac	E	—
Tragia urticifolia Nettle-leaf Noseburn	E	—
Trepocarpus aethusae Trepocarpus	S	—
Trichophorum planifolium Bashful Bulrush	E	—
Trichostema setaceum Narrowleaved Bluecurls	E	—
Trientalis borealis Northern Starflower	E	—
Trifolium reflexum Buffalo Clover	E	—
Trifolium stoloniferum Running Buffalo Clover	T	LE
Trillium nivale Snow Trillium	E	—
Trillium pusillum Least Trillium	E	—
Trillium undulatum Painted Trillium	T	—
Ulmus serotina September Elm	S	—
Utricularia macrorhiza Greater Bladderwort	E	—
Vaccinium erythrocarpum Southern Mountain Cranberry	E	—
Vallisneria americana Eelgrass	S	—
Veratrum parviflorum Appalachian Bunchflower	T	—
Veratrum woodii Wood's Bunchflower	T	—
Verbena canadensis Rose Mock-vervain	E	—
Veronica americana American Speedwell	H	—
Viburnum lantanoides Alderleaved Viburnum	E	—
Viburnum molle Softleaf Arrowwood	S	—
Viburnum nudum Possumhaw	E	—
Viburnum rafinesquianum var. *rafinesquianum* Downy Arrowwood	T	—
Viola septemloba var. *egglestonii* Eggleston's Violet	S	—
Viola walteri Walter's Violet	T	—
Vitis labrusca Northern Fox Grape	T	—
Vitis rupestris Sand Grape	T	—
Woodsia scopulina ssp. *appalachiana* Appalachian Woodsia	H	—
Xyris difformis Carolina Yellow-eyed-grass	E	—
Zizania palustris var. *interior* Indian Wild Rice	H	—
Zizaniopsis miliacea Southern Wild Rice	T	—
Animals		
Snails		
Anguispira rugoderma Pine Mountain Tigersnail	E	—
Antroselates spiralis Shaggy Cavesnail	S	—
Appalachina chilhoweensis Queen Crater	S	—
Fumonelix wetherbyi Clifty Covert	S	—
Glyphyalinia raderi Maryland Glyph	S	—
Glyphyalinia rhoadsi Sculpted Glyph	T	—
Helicodiscus notius specus A Terrestrial Snail	T	—

Table 1. Continued.

	Status KSNPC	Status U.S.
Helicodiscus punctatellus Punctate Coil	S	—
Leptoxis praerosa Onyx Rocksnail	S	—
Lioplax sulculosa Furrowed Lioplax	S	—
Lithasia armigera Armored Rocksnail	S	—
Lithasia geniculata Ornate Rocksnail	S	—
Lithasia salebrosa Muddy Rocksnail	S	—
Lithasia verrucosa Varicose Rocksnail	S	—
Mesomphix rugeli Wrinkled Button	T	—
Neohelix dentifera Big-tooth Whitelip	T	—
Paravitrea lapilla Gem Supercoil	T	—
Patera panselenus Virginia Bladetooth	S	—
Pilsbryna vanattai Honey Glyph	E	—
Pleurocera alveare Rugged Hornsnail	S	—
Pleurocera curta Shortspire Hornsnail	S	—
Rabdotus dealbatus Whitewashed Rabdotus	T	—
Rhodacme elatior Domed Ancylid	S	—
Vertigo bollesiana Delicate Vertigo	E	—
Vertigo clappi Cupped Vertigo	E	—
Vitrinizonites latissimus Glassy Grapeskin	T	—
Webbhelix multilineata Striped Whitelip	T	—
Freshwater Mussels		
Alasmidonta atropurpurea Cumberland Elktoe	E	LE
Alasmidonta marginata Elktoe	T	—
Anodontoides denigratus Cumberland Papershell	E	—
Cumberlandia monodonta Spectaclecase	E	C
Cyprogenia stegaria Fanshell	E	LE
Dromus dromas Dromedary Pearlymussel	E	LE
Epioblasma brevidens Cumberlandian Combshell	E	LE
Epioblasma capsaeformis Oyster Mussel	E	LE
Epioblasma florentina walkeri Tan Riffleshell	E	LE
Epioblasma obliquata obliquata Catspaw	E	LE
Epioblasma torulosa rangiana Northern Riffleshell	E	LE
Epioblasma triquetra Snuffbox	E	PE
Lampsilis abrupta Pink Mucket	E	LE
Lampsilis ovata Pocketbook	E	—
Lasmigona compressa Creek Heelsplitter	E	—
Obovaria retusa Ring Pink	E	LE
Pegias fabula Littlewing Pearlymussel	E	LE
Plethobasus cooperianus Orangefoot Pimpleback	E	LE
Plethobasus cyphyus Sheepnose	E	C
Pleurobema clava Clubshell	E	LE
Pleurobema oviforme Tennessee Clubshell	E	—
Pleurobema plenum Rough Pigtoe	E	LE
Pleurobema rubrum Pyramid Pigtoe	E	—
Potamilus capax Fat Pocketbook	E	LE
Potamilus purpuratus Bleufer	E	—
Ptychobranchus subtentum Fluted Kidneyshell	E	C
Quadrula cylindrica cylindrica Rabbitsfoot	T	C
Simpsonaias ambigua Salamander Mussel	T	—
Toxolasma lividus Purple Lilliput	E	—
Toxolasma texasiensis Texas Lilliput	E	—
Villosa lienosa Little Spectaclecase	S	—
Villosa ortmanni Kentucky Creekshell	T	—
Villosa trabalis Cumberland Bean	E	LE
Villosa vanuxemensis vanuxemensis Mountain Creekshell	T	—
Crustaceans		
Barbicambarus cornutus Bottlebrush Crayfish	S	—
Bryocamptus morrisoni elegans A Copepod	T	—
Caecidotea barri Clifton Cave Isopod	E	—
Cambarellus puer Swamp Dwarf Crayfish	E	—
Cambarellus shufeldtii Cajun Dwarf Crayfish	S	—
Cambarus bouchardi Big South Fork Crayfish	E	—
Cambarus buntingi Longclaw Crayfish	S	—
Cambarus friaufi Hairy Crayfish	S	—
Cambarus parvoculus Mountain Midget Crayfish	T	—
Cambarus veteranus Big Sandy Crayfish	S	—
Crangonyx caecus An Amphipod	T	—
Crangonyx castellanum An Amphipod	E	—
Crangonyx lewisi Lewis Cave Amphipod	T	—
Crangonyx longidactylus An Amphipod	T	—
Crangonyx specus An Amphipod	E	—
Gammarus bousfieldi Bousfield's Amphipod	E	—
Macrobrachium ohione Ohio Shrimp	E	—
Orconectes barri Cumberland Plateau Cave Crayfish	T	—
Orconectes bisectus Crittenden Crayfish	T	—
Orconectes burri Burr Crayfish	T	—
Orconectes inermis inermis Ghost Crayfish	S	—
Orconectes jeffersoni Louisville Crayfish	E	—
Orconectes lancifer Shrimp Crayfish	E	—
Orconectes margorectus Livingston Crayfish	T	—
Orconectes packardi Appalachian Cave Crayfish	T	—
Orconectes palmeri palmeri Gray-Speckled Crayfish	E	—
Orconectes pellucidus Mammoth Cave Crayfish	S	—
Orconectes ronaldi Mud River Crayfish	T	—
Palaemonias ganteri Mammoth Cave Shrimp	E	LE
Procambarus viaeviridis Vernal Crayfish	T	—
Pseudocandona jeanneli Jeannel's Cave Ostracod	E	—
Sagittocythere stygia An Ectocommensal Ostracod	T	—
Stygobromus vitreus An Amphipod	S	—
Insects		
Acroneuria hitchcocki Kentucky Stone	T	—
Acroneuria kosztarabi Virginia Stone	S	—
Allocapnia cunninghami Karst Snowfly	T	—
Amphiagrion saucium Eastern Red Damsel	E	—
Arigomphus maxwelli Bayou Clubtail	T	—
Arrhopalites altus A Cave Obligate Springtail	T	—
Arrhopalites bimus A Cave Obligate Springtail	T	—
Batriasymmodes quisnamus A Cave Obligate Beetle	T	—
Batrisodes henroti A Cave Obligate Beetle	T	—
Batrisodes hubrichti A Cave Obligate Beetle	T	—
Calephelis borealis Northern Metalmark	T	—
Calephelis muticum Swamp Metalmark	E	—
Callophrys irus Frosted Elfin	E	—
Calopteryx dimidiata Sparkling Jewelwing	E	—
Celithemis verna Double-ringed Pennant	H	—

Table 1. Continued.

	Status	
	KSNPC	U.S.
Cheumatopsyche helma Helma's Net-spinning Caddisfly	H	—
Dannella provonshai An Ephemerellid Mayfly	H	—
Dryobius sexnotatus Six-banded Longhorn Beetle	T	—
Erora laeta Early Hairstreak	T	—
Euphyes dukesi Dukes' Skipper	S	—
Gomphus hybridus Cocoa Clubtail	E	—
Habrophlebiodes celeteria A Leptophlebiid Mayfly	H	—
Hansonoperla hokolesqua Splendid Stone	S	—
Litobrancha recurvata A Burrowing Mayfly	S	—
Lordithon niger Black Lordithon Rove Beetle	H	—
Lytrosis permagnaria A Geometrid Moth	E	—
Maccaffertium bednariki A Heptageniid Mayfly	S	—
Manophylax butleri A Limnephilid Caddisfly	S	—
Mesamia stramineus Helianthus Leafhopper	E	—
Nannothemis bella Elfin Skimmer	E	—
Nehalennia irene Sedge Sprite	E	—
Nixe flowersi A Heptageniid Mayfly	H	—
Ophiogomphus aspersus Brook Snaketail	H	—
Ophiogomphus howei Pygmy Snaketail	T	—
Ophiogomphus mainensis Maine Snaketail	E	—
Papaipema beeriana Blazing Star Stem Borer	E	—
Papaipema eryngii Rattlesnake-master Borer Moth	E	—
Papaipema silphii Silphium Borer Moth	E	—
Papaipema sp. 5 Rare Cane Borer Moth	T	—
Papaipema speciosissima Osmunda Borer Moth	E	—
Phyciodes batesii Tawny Crescent	H	—
Poanes viator Broad-winged Skipper	T	—
Polygonia faunus Green Comma	H	—
Polygonia progne Gray Comma	H	—
Prairiana kansana A Cicadellid Leafhopper	E	—
Pseudanophthalmus abditus Concealed Cave Beetle	T	—
Pseudanophthalmus audax Bold Cave Beetle	T	—
Pseudanophthalmus caecus Clifton Cave Beetle	T	C
Pseudanophthalmus calcareus Limestone Cave Beetle	T	—
Pseudanophthalmus catoryctos Lesser Adams Cave Beetle	E	—
Pseudanophthalmus cnephosus A Cave Obligate Beetle	T	—
Pseudanophthalmus conditus Hidden Cave Beetle	T	—
Pseudanophthalmus elongatus A Cave Obligate Beetle	S	—
Pseudanophthalmus exoticus Exotic Cave Beetle	H	—
Pseudanophthalmus frigidus Icebox Cave Beetle	T	C
Pseudanophthalmus globiceps Round-headed Cave Beetle	T	—
Pseudanophthalmus horni Garman's Cave Beetle	S	—

Table 1. Continued.

	Status	
	KSNPC	U.S.
Pseudanophthalmus hypolithos Ashcamp Cave Beetle	T	—
Pseudanophthalmus inexpectatus Surprising Cave Beetle	T	—
Pseudanophthalmus major Beaver Cave Beetle	T	—
Pseudanophthalmus parvus Tatum Cave Beetle	T	C
Pseudanophthalmus pholeter Greater Adams Cave Beetle	E	—
Pseudanophthalmus pubescens intrepidus A Cave Obligate Beetle	T	—
Pseudanophthalmus puteanus Old Well Cave Beetle	T	—
Pseudanophthalmus rogersae Rogers' Cave Beetle	T	—
Pseudanophthalmus scholasticus Scholarly Cave Beetle	T	—
Pseudanophthalmus simulans Cub Run Cave Beetle	T	—
Pseudanophthalmus solivagus A Cave Obligate Beetle	S	—
Pseudanophthalmus tenebrosus Stevens Creek Cave Beetle	T	—
Pseudanophthalmus transfluvialis A Cave Obligate Beetle	S	—
Pseudanophthalmus troglodytes Louisville Cave Beetle	T	C
Pseudosinella espanita A Cave Obligate Springtail	S	—
Raptoheptagenia cruentata A Heptageniid Mayfly	H	—
Rasvena terna Vermont Sallfly	S	—
Satyrium favonius ontario Northern Oak Hairstreak	S	—
Soyedina calcarea A Stonefly	E	—
Speyeria idalia Regal Fritillary	H	—
Stylurus notatus Elusive Clubtail	E	—
Stylurus scudderi Zebra Clubtail	E	—
Tomocerus missus A Cave Obligate Springtail	T	—
Traverella lewisi A Leptophlebiid Mayfly	H	—
Tychobythinus hubrichti A Cave Obligate Beetle	T	—
Other Invertebrates		
Belba bulbipedata A Cave Obligate Mite	T	—
Galumna alata A Cave Obligate Mite	T	—
Geocentrophora cavernicola A Cave Obligate Planarian	T	—
Hesperonemastoma inops A Cave Obligate Harvestman	S	—
Kleptochthonius attenuatus A Cave Obligate Pseudoscorpion	T	—
Kleptochthonius cerberus A Cave Obligate Pseudoscorpion	S	—
Kleptochthonius erebicus A Cave Obligate Pseudoscorpion	T	—
Kleptochthonius hageni A Cave Obligate Pseudoscorpion	S	—
Kleptochthonius hubrichti A Cave Obligate Pseudoscorpion	T	—

Table 1. Continued.

	Status	
	KSNPC	U.S.
Kleptochthonius microphthalmus A Cave Obligate Pseudoscorpion	T	—
Macrocheles stygius A Cave Obligate Mite	T	—
Macrocheles troglodytes A Cave Obligate Mite	T	—
Pseudotremia amphiorax A Cave Obligate Milliped	T	—
Pseudotremia carterensis A Cave Obligate Milliped	S	—
Pseudotremia merops A Cave Obligate Milliped	T	—
Pseudotremia spira A Cave Obligate Milliped	T	—
Pseudotremia unca A Cave Obligate Milliped	T	—
Sphalloplana buchanani A Cave Obligate Planarian	T	—
Tyrannochthonius hypogeus A Cave Obligate Pseudoscorpion	S	—
Fishes		
Acipenser fulvescens Lake Sturgeon	E	—
Alosa alabamae Alabama Shad	E	—
Amblyopsis spelaea Northern Cavefish	S	—
Ammocrypta clara Western Sand Darter	E	—
Atractosteus spatula Alligator Gar	E	—
Chrosomus cumberlandensis Blackside Dace	T	LT
Cyprinella camura Bluntface Shiner	E	—
Cyprinella venusta Blacktail Shiner	S	—
Erimystax insignis Blotched Chub	E	—
Erimyzon sucetta Lake Chubsucker	T	—
Esox niger Chain Pickerel	S	—
Etheostoma chienense Relict Darter	E	LE
Etheostoma cinereum Ashy Darter	S	—
Etheostoma fusiforme Swamp Darter	E	—
Etheostoma lemniscatum Tuxedo Darter	E	LE
Etheostoma lynceum Brighteye Darter	E	—
Etheostoma maculatum Spotted Darter	T	—
Etheostoma microlepidum Smallscale Darter	E	—
Etheostoma parvipinne Goldstripe Darter	E	—
Etheostoma proeliare Cypress Darter	T	—
Etheostoma pyrrhogaster Firebelly Darter	E	—
Etheostoma sagitta sagitta Cumberland Arrow Darter	S	—
Etheostoma sagitta spilotum Kentucky Arrow Darter	T	C
Etheostoma susanae Cumberland Darter	E	PE
Etheostoma swaini Gulf Darter	E	—
Etheostoma tecumsehi Shawnee Darter	S	—
Fundulus chrysotus Golden Topminnow	E	—
Fundulus dispar Starhead Topminnow	E	—
Hybognathus hayi Cypress Minnow	E	—
Hybognathus placitus Plains Minnow	S	—
Hybopsis amnis Pallid Shiner	E	—
Ichthyomyzon castaneus Chestnut Lamprey	S	—
Ichthyomyzon fossor Northern Brook Lamprey	T	—
Ichthyomyzon greeleyi Mountain Brook Lamprey	T	—
Ictiobus niger Black Buffalo	S	—
Lampetra appendix American Brook Lamprey	T	—
Lampetra sp. 1 Undescribed Terrapin Creek brook lamprey	E	—
Lepomis marginatus Dollar Sunfish	E	—
Lepomis miniatus Redspotted Sunfish	T	—

Table 1. Continued.

	Status	
	KSNPC	U.S.
Lota lota Burbot	S	—
Macrhybopsis gelida Sturgeon Chub	E	—
Macrhybopsis meeki Sicklefin Chub	E	—
Menidia beryllina Inland Silverside	T	—
Moxostoma poecilurum Blacktail Redhorse	E	—
Nocomis biguttatus Hornyhead Chub	S	—
Notropis albizonatus Palezone Shiner	E	LE
Notropis hudsonius Spottail Shiner	S	—
Notropis maculatus Taillight Shiner	T	—
Notropis sp. 4 Sawfin Shiner	E	—
Noturus exilis Slender Madtom	E	—
Noturus hildebrandi Least Madtom	E	—
Noturus phaeus Brown Madtom	E	—
Noturus stigmosus Northern Madtom	S	—
Percina macrocephala Longhead Darter	E	—
Percina squamata Olive Darter	E	—
Percopsis omiscomaycus Trout-perch	S	—
Phenacobius uranops Stargazing Minnow	S	—
Platygobio gracilis Flathead Chub	S	—
Scaphirhynchus albus Pallid Sturgeon	E	LE
Thoburnia atripinnis Blackfin Sucker	S	—
Typhlichthys subterraneus Southern Cavefish	S	—
Umbra limi Central Mudminnow	T	—
Amphibians		
Amphiuma tridactylum Three-toed Amphiuma	E	—
Cryptobranchus alleganiensis alleganiensis Eastern Hellbender	E	—
Eurycea guttolineata Three-lined Salamander	T	—
Hyla avivoca Bird-voiced Treefrog	S	—
Hyla gratiosa Barking Treefrog	S	—
Hyla versicolor Gray Treefrog	S	—
Plethodon cinereus Redback Salamander	S	—
Plethodon wehrlei Wehrle's Salamander	E	—
Rana areolata circulosa Northern Crawfish Frog	S	—
Rana pipiens Northern Leopard Frog	S	—
Reptiles		
Apalone mutica mutica Midland Smooth Softshell	S	—
Chrysemys dorsalis Southern Painted Turtle	T	—
Clonophis kirtlandii Kirtland's Snake	T	—
Elaphe guttata Corn Snake	S	—
Eumeces anthracinus Coal Skink	T	—
Eumeces inexpectatus Southeastern Five-lined Skink	S	—
Farancia abacura reinwardtii Western Mud Snake	S	—
Lampropeltis triangulum elapsoides Scarlet Kingsnake	S	—
Macrochelys temminckii Alligator Snapping Turtle	T	—
Nerodia cyclopion Green Water Snake	E	—
Nerodia erythrogaster neglecta Copperbelly Water Snake	S	—
Nerodia fasciata confluens Broad-banded Water Snake	E	—
Ophisaurus attenuatus longicaudus Eastern Slender Glass Lizard	T	—
Pituophis melanoleucus melanoleucus Northern Pine Snake	T	—

Table 1. Continued.

	Status KSNPC	Status U.S.
Sistrurus miliarius streckeri Western Pygmy Rattlesnake	T	—
Thamnophis proximus proximus Western Ribbon Snake	T	—
Thamnophis sauritus sauritus Eastern Ribbon Snake	S	—
Breeding Birds		
Accipiter striatus Sharp-shinned Hawk	S	—
Actitis macularius Spotted Sandpiper	E	—
Aimophila aestivalis Bachman's Sparrow	E	—
Ammodramus henslowii Henslow's Sparrow	S	—
Anas clypeata Northern Shoveler	E	—
Anas discors Blue-winged Teal	T	—
Ardea alba Great Egret	T	—
Asio flammeus Short-eared Owl	E	—
Asio otus Long-eared Owl	E	—
Bartramia longicauda Upland Sandpiper	H	—
Botaurus lentiginosus American Bittern	H	—
Bubulcus ibis Cattle Egret	S	—
Certhia americana Brown Creeper	E	—
Chondestes grammacus Lark Sparrow	T	—
Circus cyaneus Northern Harrier	T	—
Cistothorus platensis Sedge Wren	S	—
Corvus corax Common Raven	T	—
Corvus ossifragus Fish Crow	S	—
Dendroica fusca Blackburnian Warbler	T	—
Dolichonyx oryzivorus Bobolink	S	—
Egretta caerulea Little Blue Heron	E	—
Egretta thula Snowy Egret	E	—
Empidonax minimus Least Flycatcher	E	—
Falco peregrinus Peregrine Falcon	E	—
Fulica americana American Coot	E	—
Gallinula chloropus Common Moorhen	T	—
Haliaeetus leucocephalus Bald Eagle	T	—
Ictinia mississippiensis Mississippi Kite	S	—
Ixobrychus exilis Least Bittern	T	—
Junco hyemalis Dark-eyed Junco	S	—
Lophodytes cucullatus Hooded Merganser	T	—
Nyctanassa violacea Yellow-crowned Night-heron	T	—
Nycticorax nycticorax Black-crowned Night-heron	T	—
Pandion haliaetus Osprey	S	—
Passerculus sandwichensis Savannah Sparrow	S	—
Phalacrocorax auritus Double-crested Cormorant	T	—
Pheucticus ludovicianus Rose-breasted Grosbeak	S	—
Podilymbus podiceps Pied-billed Grebe	E	—
Pooecetes gramineus Vesper Sparrow	E	—
Rallus elegans King Rail	E	—
Riparia riparia Bank Swallow	S	—
Sitta canadensis Red-breasted Nuthatch	E	—
Sternula antillarum athalassos Interior Least Tern	T	LE
Thryomanes bewickii Bewick's Wren	S	—
Tyto alba Barn Owl	S	—
Vermivora chrysoptera Golden-winged Warbler	T	—
Vireo bellii Bell's Vireo	S	—
Wilsonia canadensis Canada Warbler	S	—
Mammals		
Clethrionomys gapperi maurus Kentucky Red-backed Vole	S	—
Corynorhinus rafinesquii Rafinesque's Big-eared Bat	S	—
Corynorhinus townsendii virginianus Virginia Big-eared Bat	E	LE
Mustela nivalis Least Weasel	S	—
Myotis austroriparius Southeastern Myotis	E	—
Myotis grisescens Gray Myotis	T	LE
Myotis leibii Eastern Small-footed Myotis	T	—
Myotis sodalis Indiana Bat	E	LE
Nycticeius humeralis Evening Bat	S	—
Peromyscus gossypinus Cotton Mouse	T	—
Sorex cinereus Cinereus Shrew	S	—
Sorex dispar blitchi Long-tailed Shrew	E	—
Spilogale putorius Eastern Spotted Skunk	S	—
Ursus americanus American Black Bear	S	—
Natural Communities		
Acid seep/bog	—	S
Appalachian seep/bog	—	T
Bluegrass mesophytic cane forest	—	E
Bluegrass woodland	—	E
Bottomland hardwood forest	—	S
Bottomland lake	—	S
Bottomland marsh	—	T
Bottomland ridge/terrace forest	—	E
Bottomland slough	—	T
Calcareous seep/bog	—	E
Coastal Plain forested acid seep	—	E
Coastal Plain mesophytic cane forest	—	T
Coastal Plain slough	—	T
Cumberland highlands forest	—	E
Cumberland Mountains pitch pine woodland	—	E
Cumberland Plateau gravel/cobble bar	—	E
Cumberland Plateau sandstone glade	—	E
Cypress (tupelo) swamp	—	E
Dolomite glade	—	E
Limestone barrens (open woodland)	—	T
Limestone flat rock glade	—	E
Limestone slope glade	—	S
Limestone/dolomite prairie	—	E
Sand bar	—	S
Sandstone barrens (open woodland)	—	E
Sandstone prairie	—	E
Shawnee Hills sandstone glade	—	T
Shrub swamp	—	T
Sinkhole/depression marsh	—	E
Sinkhole/depression pond	—	T
Tallgrass prairie	—	E
Wet bottomland hardwood forest	—	T
Wet depression/sinkhole forest	—	T
Wet meadow	—	E
Wet prairie	—	E
Xerohydric flatwoods	—	E

[1] Species without English (common) names have not been assigned official names.

- Insects (estimated to be 15,202): unknown
- Fishes (245): 25.3%
- Amphibians and reptiles (107): 25.2%
- Breeding birds (168): 28.6%
- Mammals (67): 20.9%
- Natural communities—(63): 57%.

Nineteen plant and 47 animal taxa are currently presumed extinct or extirpated from Kentucky (Tables 2, 3) (KSNPC 2010).

DISCUSSION

These lists summarize the best available and current knowledge on the status of Kentucky's rare plants, animals, and natural communities as of 2010. Many species that are believed extinct or extirpated from Kentucky have experienced range-wide declines due to habitat destruction, stream modification, and pollution (Jones 2005; Poff et al. 2007). Subsequently, these losses and declines in biodiversity are also felt in ecosystems (Hooper et al. 2005; Vaughn 2010). The potential long-term effect of climate change on Kentucky's biodiversity is an area of research that is needed for future management considerations. In particular, knowledge on the extent and design of biodiversity corridors for use in mitigating the effects of climate change is needed.

We feel that the inclusion of natural communities as part of this publication is a significant addition to the rare and extirpated species list. Many types of natural communities are common in the state, but high quality examples of any natural community type are rare. Therefore, all natural communities classified by KSNPC (including those not listed here) are monitored in Kentucky. The high percentage of communities that are rare and threatened reflects the widespread modification of the landscape by humans and the lack of sufficient protection. KSNPC hopes that publishing a list of rare natural communities to the wider scientific community will help to strengthen the goal of recovery and preservation of Kentucky's rich natural diversity.

Efforts to standardize community classification at the national level (Grossman 1998) are still on-going. Due to an incomplete national classification, many state natural heritage programs have developed their own community classifications. If a widely accepted standard is developed in the future,

Table 2. Diversity and conservation status of the major groups of organisms and natural communities in Kentucky, 2010.

Number of Kentucky taxa or communities	Lichens	Mosses	Vascular plants	Natural communities	Snails[1,2]	Freshwater mussels	Crustaceans	Insects	Other invertebrates	Fishes	Amphibians	Reptiles	Breeding birds	Mammals
Native	unknown	317	2030	63	251	103	unknown	15,202[3]	unknown	245	53	54	168	67
Exotic	0	0	570	unknown	15	0	unknown	unknown	unknown	23	0	1	4	5
KSNPC Endangered	1	12	157	20	4	28	12	20	0	32	3	2	15	4
KSNPC Threatened	0	5	108	11	8	5	13	35	14	12	1	8	15	3
KSNPC Special Concern	0	0	55	5	15	1	8	13	5	18	6	7	16	7
KSNPC Historical	0	0	50	0	0	0	0	14	0	0	0	0	2	0
Presumed Extinct or Extirpated	0	0	19	0	0	20	0	2	0	9	0	1	9[4]	4
Extant Federally Threatened or Endangered	0	0	8	0	0	16	1	0	0	5	0	0	1	4
Extant Federal Candidate	0	0	3	0	0	4	0	4	0	1	0	0	0	0
Extant Proposed for Federal Listing	0	0	0	0	0	1	0	0	0	1	0	0	0	0

[1] Total excludes fossils, includes slugs, and is estimated for freshwater snails.
[2] Totals for slugs and land snails courtesy of D. Dourson (Copperhead Consulting, pers. comm., 23 July 2010).
[3] Estimated.
[4] Two non-breeding birds are considered Extinct or Extirpated.

Table 3. Plants and animals presumed extinct or extirpated from Kentucky.

	U.S. Status[1]
Plants	
Vascular Plants	
Anemone canadensis Canada Anemone	—
Argyrochosma dealbata Powdery Cloakfern	—
Callirhoe alcaeoides Clustered Poppy-mallow	—
Caltha palustris var. *palustris* Marsh Marigold	—
Coeloglossum viride Long-bract Green Orchis	—
Cypripedium reginae Showy Lady's-slipper	—
Dryopteris ludoviciana Southern Shield Wood Fern	—
Lysimachia fraseri Fraser's Loosestrife	—
Lysimachia radicans Trailing Loosestrife	—
Monarda punctata Spotted Bee-balm	—
Orbexilum stipulatum Stipuled Scurf-pea	—
Pedicularis lanceolata Swamp Lousewort	—
Physostegia intermedia Slender Dragon-head	—
Plantago cordata Heart-leaved Plantain	—
Polytaenia nuttallii Prairie Parsley	—
Pyrola americana American Wintergreen	—
Saxifraga pensylvanica Swamp Saxifrage	—
Scirpus microcarpus Small-fruit Bulrush	—
Xerophyllum asphodeloides Eastern Turkeybeard	—
Animals	
Freshwater Mussels	
Epioblasma arcaeformis Sugarspoon	—
Epioblasma biemarginata Angled Riffleshell	—
Epioblasma cincinnatiensis Cincinnati Riffleshell	—
Epioblasma flexuosa Leafshell	—
Epioblasma florentina florentina Yellow Blossom	LE
Epioblasma haysiana Acornshell	—
Epioblasma lewisii Forkshell	—
Epioblasma obliquata perobliqua White Catspaw	LE
Epioblasma personata Round Combshell	—
Epioblasma propinqua Tennessee Riffleshell	—
Epioblasma sampsonii Wabash Riffleshell	—
Epioblasma stewardsonii Cumberland Leafshell	—
Epioblasma torulosa torulosa Tubercled Blossom	LE
Hemistena lata Cracking Pearlymussel	LE
Leptodea leptodon Scaleshell	LE
Lexingtonia dolabelloides Slabside Pearlymussel	C
Plethobasus cicatricosus White Wartyback	LE
Quadrula fragosa Winged Mapleleaf	LE
Quadrula tuberosa Rough Rockshell	—
Villosa fabalis Rayed Bean	PE
Insects	
Nicrophorus americanus American Burying Beetle	LE
Pentagenia robusta Robust Pentagenian Burrowing Mayfly	—
Fishes	
Ammocrypta vivax Scaly Sand Darter	—
Crystallaria cincotta Diamond Darter	C
Erimystax x-punctatus Gravel Chub	—
Etheostoma microperca Least Darter	—
Hemitremia flammea Flame Chub	—
Ichthyomyzon gagei Southern Brook Lamprey	—
Moxostoma lacerum Harelip Sucker	—
Moxostoma valenciennesi Greater Redhorse	—
Percina burtoni Blotchside Logperch	—
Reptiles	
Masticophis flagellum flagellum Coachwhip	—
Breeding Birds	
Anhinga anhinga Anhinga	—
Campephilus principalis Ivory-billed Woodpecker	LE
Chlidonias niger Black Tern	—
Conuropsis carolinensis Carolina Parakeet	—
Ectopistes migratorius Passenger Pigeon	—
Elanoides forficatus Swallow-tailed Kite	—
Picoides borealis Red-cockaded Woodpecker	LE
Tympanuchus cupido Greater Prairie-chicken	—
Vermivora bachmanii Bachman's Warbler	LE
Non-Breeding Birds	
Cygnus buccinator Trumpeter Swan	—
Grus americana Whooping Crane	LE
Mammals	
Bos bison American Bison	—
Canis lupus Gray Wolf	—
Canis rufus Red Wolf	LE
Puma concolor couguar Eastern Cougar	LE

[1] The U.S. Status provided here refers to the current status of the taxon under the U.S. Endangered Species Act (USESA) as interpreted for its range within the state of Kentucky.

KNSPC will make changes to its classification and nomenclature where appropriate.

Although KSNPC continues to refine and expand this list to include new taxa, it does not adequately treat or include several groups of organisms found in Kentucky. As previously mentioned (KSNPC 2000) the fungi, liverworts, insects, macro- and microcrustaceans (amphipods, isopods, zooplankton, etc.), and other groups are important aspects of Kentucky's biodiversity but nevertheless remain poorly known within the state.

As with previous iterations of this list, we welcome recommendations with regard to the conservation status of native taxa and communities or those that should be added to or deleted from the list. Comments or recommendations should be forwarded to the agency director of KSNPC who will pass on such information to appropriate staff members for review and response. Information about delisted and other taxa or communities is maintained in databases, Geographic Information Systems, and catalogues for future reference. Interested persons may contact KSNPC at any time for the current status of Kentucky's rare organisms or communities or visit our website (http://www.naturepreserves.

ky.gov/inforesources/reports_pubs.htm) for the most recent version of this list.

Various iterations of these lists (Branson et al. 1981; Warren et al. 1986; KSNPC 1996, 1997, 1999, 2000, 2001, 2004, 2005; Abernathy et al. 2010) have refined both conservation status of Kentucky's species and added new taxonomic and ecological groups. We hope this information is used by interested citizens, agencies, and various organizations in Kentucky to protect and preserve the natural diversity of the state, as well as to drive further research on the various groups.

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Major Impacts and Challenges facing Kentucky's Streams and Wetlands: A Summary of Agency, Other Expert, and Stakeholder Views

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ABSTRACT

To protect our nation's water resources, the United States Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE) have declared a goal of "no net loss" of our nation's water and wetland resources to be a national priority for the past 20 years. To meet this objective, the EPA has encouraged states to develop state wetland conservation plans and incorporate stakeholders into the development of those plans. Recently, the Kentucky Division of Water initiated a streams and wetlands conservation planning process. As part of the process, we conducted surveys and interviews of Kentucky stakeholders in stream and wetlands issues. Results of the surveys emphasized three impacts of concern: sewer overflows and straight pipes, coal and energy development, and residential growth. Stakeholders had wide areas of agreement, although their perspectives were not entirely uniform. Perception of the relative importance of some types of impacts was dependent on job position, level of awareness, and watershed region. Kentucky's first phase planning process illustrates the importance of soliciting watershed-based multi-stakeholder input in conservation planning as mandated by the EPA. We conclude by recommending directions for a second phase of planning and a subsequent implementation stage for the streams and wetlands conservation planning process.

KEY WORDS: Conservation planning, stakeholders, streams, surveys, wetlands, Kentucky

INTRODUCTION

Across the United States, more than 50% of wetlands have been lost since historical times (Dahl 1999), and upwards of 80% of wetland area have been lost in Kentucky (Dahl 2000). To thwart this continued decline, the United States Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (USACE) declared "no net loss" of our nation's water and wetland resources as a national priority for the past 20 years (World Wildlife Fund 1992). To meet the objective of no net loss (and even net gain), the EPA as well as the scientific community has encouraged states to develop state wetland conservation plans (La Peyre et al. 2001) that are thought to have been effective in conserving wetlands (Brody and Highfield 2005).

A review of state wetland conservation plans available online showed that, over the years, many states (31) have developed comprehensive plans and strategies to start to protect, conserve, and mitigate the impacts of various human activities on water resources. Most of the initial state plans first developed in the early to mid 1990s advocated more coordinated efforts at encouraging landowners and other stakeholders to participate in wetland conservation and water quality improvement programs. In addition, most of the plans advocated better monitoring of state water resources through mapping and

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cataloguing wetlands for better protection, shared record-keeping of permitting processes, and better scientific documentation of the successes or failures of stream and wetland mitigation and restoration projects (e.g., Arkansas Multi-agency Wetland Planning Team 1992; California Department of Water Resources 1993; Tennessee Department of Environment and Conservation 1998).

Since the advent of the first plans in the 1990s, many states have included more collaborative watershed management approaches toward stream and wetlands protection as there seems to be increasing recognition that protecting complex and dynamic water systems requires a close inter-working collaboration between agencies, scientists, and other stakeholders at all levels (Borre et al. 2001; Prell et al. 2007; Bonnell and Koontz 2007). The co-management approach that requires resource users and government agencies to work together to develop more sustainable watershed practices (Heikkila and Gerlak 2005) has been encouraged by the EPA. Former EPA Administrator Christine Whitman stated that one of the most important environmental guiding principles to managing water resources is a "watershed approach" (EPA internal memo 2002; http://www.epa.gov/owow/watershed/memo.html). Wetland Program Development Grant applications administered by the EPA Office of Wetlands Oceans, and, Watersheds are now required to integrate collaborative stakeholder approaches into wetland conservation planning proposals (http://www.epa.gov/wetlands/grantguidelines/).

For example, the Montana Wetland Council, that guides its state's planning process, meets regularly and includes participants from multiple state and federal agencies, tribal governments, and other stakeholder groups. Over the last several years, the Montana Wetland Council has put forward a series of strategies to better educate the public and local governments, train professionals, identify vulnerable wetlands, and track state and national policy proposals that may impact wetlands and stream management (Montana Department of Environmental Quality 2008). Planning processes such as Montana's are now widely accepted as reasonable compliments or even alternatives to top-down regulatory approaches to resource management. Stakeholder participation in program building and policy development is thought to increase stakeholder acceptance and subsequent compliance in the conservation and protection of resources (Ostrom 1999; Falkenmark et al. 2004).

In short, it has become a commonly accepted practice to solicit broad input from users and other sectors in the development of conservation programs and regulations. Without such input, conservation policies may be ineffective because they are not perceived as legitimate. In addition to encouraging "buy-in" and compliance, collaborative conservation approaches build the social capital and knowledge to manage resources over the long-term (Lubell 2004; Sanderson and Kindon 2004; Heikkila and Gerlak 2005; Prell et al. 2007). The participatory methods used in collaborative co-management models put stakeholders at parity with scientists, thus they generate a more holistic and democratic understanding of water resource management. While it is widely accepted that watershed specific approaches are central to on-the-ground water resource management, there is now a growing recognition that co-management of natural resources must occur at larger scales to influence sustainable development policies and practices regionally, nationally, and globally (Heikkila and Gerlak 2005).

In 2008, the Kentucky Division of Water (KDOW) initiated the first phase of its own streams and wetlands conservation planning process. In this phase, surveys and interviews of multiple stream and wetlands management stakeholders were used to assess stakeholder perceptions of the current state of Kentucky streams, wetlands, and potential policy solutions to major impacts. Here we report findings from the first phase of a KDOW-funded project focusing primarily on current impacts to streams and wetlands and implications of the findings for future planning processes.

METHODS

Following on the successful model developed by the Montana Wetland Council (Saul 2008), we applied standard social scientific research methods (Carr and Halvorsen 2001; Leach 2002), which included the development

of a steering committee, surveys, and formal interviews with stakeholders and experts. Through the use of these multiple methods we collected stakeholder and other expert input into a potential planning framework to mitigate and preempt the further loss of stream and wetland resources. Our methods and instruments for collecting input into first phase planning processes for Kentucky are summarized below (Carr and Halvorsen 2001; Leach 2002).

Steering Committee

A steering committee was assembled to provide policy direction and guidance into Kentucky's first phase of streams and wetlands conservation planning. At the start of this project, we consulted with the KDOW to identify approximately 15 state, federal, and university people who had been involved in stream and wetlands conservation, restoration, and/or mitigation projects within the state. The 15 officials and faculty members who were first identified readily accepted invitation to sit on the steering committee. However, over the course of the next eight weeks, this multi-agency-university steering committee expanded to include other state and federal employees who also were involved in watershed and water management issues. All total, these state and federal employees included employees from the Kentucky Division of Water, Kentucky Department of Fish and Wildlife Resources, Kentucky Division of Mine Permits, Abandoned Mine Lands, Kentucky Division of Geographic Information, Kentucky Department of Transportation, U.S. Geological Survey, U.S. Fish and Wildlife Resources, U.S. Natural Resource Conservation Service, U.S. Department of Agriculture and U.S. Forest Service. Several others with years of experience but retired from their government posts also volunteered to provide input and perspective into the strategic planning process. Thus, from the original 15-member list, the steering committee expanded into a 43-member committee of university, regulatory, and other agency experts by the project's close.

To obtain their guidance and direction we held a series of moderated panels with steering committee members during which panelists were asked to comment on a series of topics. First, panelists were asked to provide comments regarding current efforts in Kentucky to conserve and restore stream and wetland areas. Panelists were also asked to specify agencies, organizations and/or partnerships that seemed most effective in conserving or restoring Kentucky's streams and wetlands. Steering committee members were then asked to reflect on the top two or three potential opportunities facing conservation and restoration Kentucky's streams and wetlands. They were also asked to reflect on the major challenges confronting streams and wetlands protection and conservation. Finally, they were asked their views on the most important change the state could make to ensure no further loss of Kentucky's streams and wetland resources and to protect their long-term health and viability (Table 1).

Fourteen moderated panel discussions were held over an 8-week period from February through March 2008 at Eastern Kentucky University, Richmond, KY. Panel discussions were held in conjunction with two university courses, "Wetlands Wildlife Management" in the Department of Biological Sciences (David Brown, instructor) and "Community-based Research" in the Department of Anthropology, Sociology and Social Work (Stephanie McSpirit, instructor). During each panel, a different student from one of the courses served as moderator and asked the set of structured interview questions to each panelist. Panelists were asked to consider and respond to each question before proceeding to the next one. Following the question set, students and faculty that were present were able to ask further questions of the panelists. All moderated panels (15 total) were videotaped and were available to other students and other steering committee members for review through a university portal. Steering committee members who were unable to attend a moderated session were interviewed by telephone and the audio was digitally recorded. All recordings from panel and phone interviews were then transcribed. Based upon review of the transcripts, it seemed the richest commentary came from responses to the following questions: 1) "opportunities and challenges facing streams and wetlands protection," 2) "single most important change we need to make," and 3) views on "no net loss"

Table 1. Interview questions used in steering committee panels and over-the-telephone interviews with stakeholders in Kentucky's streams and wetlands.

1. How involved are you in wetland and stream related issues?
2. Would you consider yourself more involved in streams or wetlands related issues?
3. What would you consider as your major role/job position in relation to streams and wetlands?
4. In which watershed is most of your work based and/or with which watershed are you most familiar? (Please list all that apply).

Substantive Questions

5. What are your thoughts regarding current efforts in Kentucky to conserve and restore stream and wetland areas?
6. What agencies, organizations and/or partnerships do you see as most effective in conserving or restoring Kentucky's streams and wetlands?
7. In your opinion, what enables them to be effective?
8. What do you see as the top 2 or 3 potential opportunities for conserving and restoring Kentucky's streams and wetlands in the years ahead?
9. What do you see as the top 2 or 3 challenges or barriers to conserving and restoring Kentucky's streams and wetlands in the years ahead?
10. What is the most important change to make in the years ahead to ensure the long-term health and viability of Kentucky's streams and wetlands?
11. What is your view of Kentucky's success in ensuring "no net loss" of streams and wetlands?
12. If you could offer one critical piece of advice to those doing long-term strategic planning for Kentucky's streams and wetlands, what would that be?
13. Is there anything you want to add that we did not address?

(Questions 8, 10, 11, Table 1) and subsequently, responses to these questions were categorized based upon theme or topic and then compiled in accord with standard qualitative (content-analysis) methods.

Other Stakeholders

Along with input from the multi-agency/university steering committee, individuals from other stakeholder groups across the state were interviewed to provide additional guidance and a broader perspective. Since these stakeholders were not public members of our steering committee, we followed standard Institutional Review Board protocols of protecting their anonymity and confidentiality in any further reporting of their commentaries and interviews. A university research team, comprised of upper-division undergraduate students from Sociology and Biology, who were enrolled in McSpirit's Community-based Research course, collected additional input through telephone interviews with stakeholders from across the state. These university students were trained in standard telephone interview methods whereby stakeholder participants were asked to respond to the same set of questions as steering committee members. Telephone interviews took place over a three week period and also were digitally-recorded, with participant permission. Recordings were then transcribed by university students enrolled in the community-based field research class and analyzed for key themes and policy directions.

In total, 44 people from across Kentucky were interviewed by phone and asked to provide input into this phase of Kentucky's streams and wetlands conservation planning process. Interviewed people represented various private and public groups. Private organizations represented in interviews included environmental organizations, sportsmen clubs, engineering firms, farmers, and coal-industry workers. Public representatives included flood plain managers, Conservation District Representatives, Watershed Basin Coordinators, Water Utility and Sanitation District personnel, and other government agencies employees. We drew upon both the telephone interviews with stakeholders and the panel interviews with steering committee members to provide more substance and depth to the findings from the online survey.

Online Survey

An online survey was launched during the period of the telephone interviews. The survey targeted groups and people who in some way were knowledgeable and/or involved in streams and wetlands issues. To identify these

Table 2. Descriptive summary of survey respondents (n = 723) by job position (A), level of involvement (B), and watershed (C). Values are percentages with number of respondents in parentheses.

A. Job position					
State/federal employee	24% (175)	Environmentalist	4 (26)	Private engineer	4 (28)
Permit holder	1 (6)	Outreach and education	5 (33)	Private attorney	1 (2)
Developer	1 (2)	Water works professional	1 (3)	Non-profit/Advocacy	4 (28)
Landowner	8 (54)	Flood plain manager	6 (43)	Hunting/fishing	8 (56)
Farmer	9 (62)	Local official	4 (29)	Concerned citizen	8 (60)
Coal mining	3 (22)	University scientist	4 (31)	Other	8 (59)
B. Level of involvement in streams and wetland related issues:					
Very involved	24% (173)				
Involved	29 (211)				
Somewhat involved	36 (262)				
Not involved	10 (77)				
C. Watershed region in which respondent worked or is most familiar:					
Kentucky River	22% (159)	Licking River[a]	10 (74)		
Salt River[a]	4 (43)	Green/Tradewater[b]	12 (86)		
Upper Cumberland River	8 (53)	Four Rivers Basin	6 (42)		
Big/Little Sandy & Tygarts	5 (36)	Entire state	14 (99)		
Ohio River	9 (62)	Other	8 (56)		

[a] Includes minor Ohio River Tributaries.
[b] Includes major Ohio River Tributaries.

groups and people, lists of various relevant stakeholders and stakeholder groups were compiled by members of the university student research team prior to the survey launch date. Targeted groups included, as above, federal and state agency staff working in watershed and water management issues, flood plain managers, private engineers, Area Development Districts, and environmental groups. The online survey asked respondents to rate their involvement in wetland and stream issues, to report their job position or role in relation to streams and wetlands, and to report the watershed in which most of their work was based or which they are most familiar. After the descriptive questions, respondents were asked to rate each of 12 potential impacts or threats facing Kentucky's streams and wetlands based on a 4-level scale from "very serious" to "not serious" (Table 3). The list of potential impacts was developed in consultation with the Kentucky Division of Water.

Statistical Analysis

We report first on job position, level of involvement, and watershed affiliation of respondents to describe our pool of survey respondents. We then report on how respondent's ranked each of the 12 listed potential impacts to Kentucky's streams and wetlands. After identifying, the top three identified impacts by stakeholders statewide, we further analyze each of these impacts, through the use of contingency table chi-square analysis (crosstabs). The standard bivariate tables allowed us to test for significant differences ($\alpha = 0.05$) in perceptions and levels of concern among stakeholders based upon job position, level of involvement and awareness and among watersheds.

RESULTS AND DISCUSSION

Survey Results

Using the online survey software, we were able to determine that of the 1077 people who opened the survey to consider it, 723 completed the survey (response rate = 67%). Respondents represented a broad variety of job positions, with most working in state or federal agencies (Table 2A). Most respondents also reported being in some way involved in stream and wetland issues (Table 2B). Watershed regions from across the state were listed by respondents as their location of work or familiarity, and thus the survey appeared to have effectively sampled stakeholders from all of the major Kentucky watersheds (Table 2C).

Stakeholders rated the impacts from development (sewage, residential growth, and

Table 3. Perceived degree of impact by type to Kentucky's streams and wetlands. Respondents were asked to evaluate impacts in each of the following categories. Total sample size of respondents varies due to "don't know" responses removed from the analyses.

	Very serious	Serious	Somewhat serious	Not a serious impact
Timber harvesting (n = 676)	24(%)	32	32	12
Road/Transportation development (n = 693)	25	37	30	8
Coal/energy development (n = 665)	43	28	21	9
Storm water run-off (n = 703)	35	34	24	7
Sewer overflows/straight pipes (n = 706)	57	28	13	2
Invasive exotic species (n = 658)	29	33	27	11
Level of education/understanding (n = 693)	37	34	21	9
Current enforcement of laws (n = 648)	23	29	31	17
Current state/federal regulations (n = 655)	19	37	34	10
Agriculture impacts to water quality (n = 692)	30	33	29	8
Water withdrawals from agriculture (n = 715)	10	26	36	28
Residential growth (n = 715)	37	34	24	4

storm water) as well as the effects of coal mining as some of the most serious ("very serious") threats facing Kentucky's streams and wetlands (Table 3, Figure 1). Most notable was that the majority of stakeholders rated sewer overflows and straight pipes as very serious. Sewers and straight pipes were followed by coal and energy development, residential growth, and storm water. In the following sub-sections we provide further breakdowns on each of the top three priority threats facing streams and wetlands protection based upon job position, level of involvement, and awareness by watershed.

Sewer overflows and straight pipes. Re-Respondents involved in non-profit/advocacy work on the environment and those who self-identified as sportsmen (hunting/fishing) were most likely to perceive the threats from sewer overflows and straight pipes as a major detriment to Kentucky's water resources. Nearly three-quarters of people in both groups rated

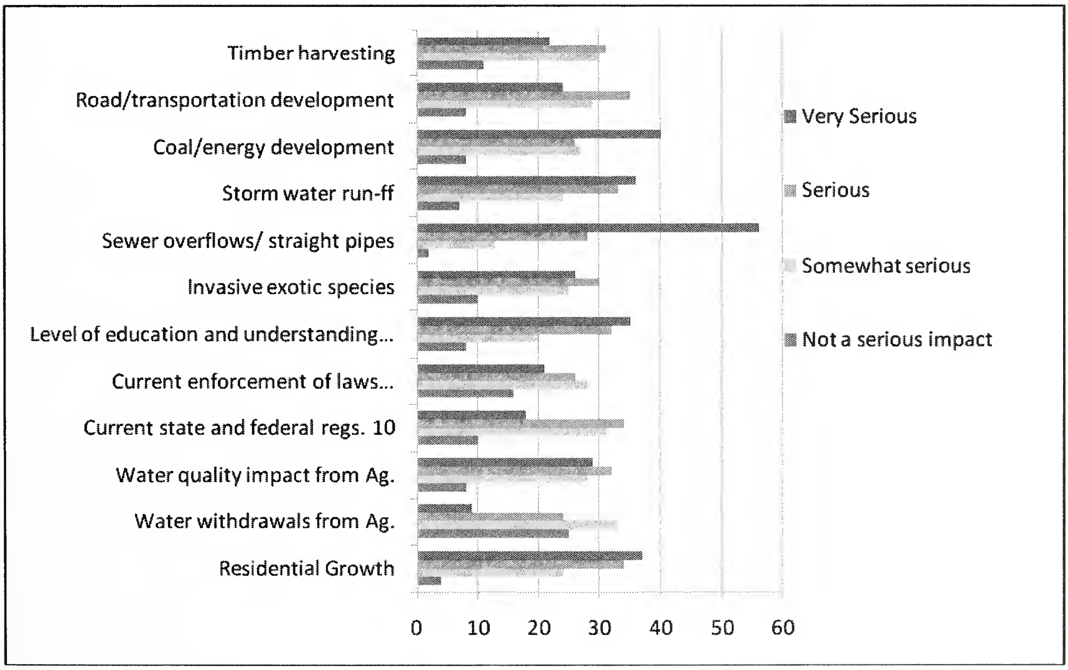

Figure 1. Perceived Impacts to Kentucky's Streams and Wetlands based on stakeholder surveys (N = 773). Respondents were asked to evaluate impacts in each of the following categories.

Table 4. Percent of respondents reporting sewer overflows and straight pipes as a "very serious impact" by job position (A), level of involvement (B), level of awareness (C), and by watershed region (D).

A. Primary role or job position					
State/federal employee	52(%)	Environmentalist	64	Private engineer	63
Permit holder	–[a]	Outreach and education	44	Private attorney	–[a]
Developer	–[a]	Water works professional	–[a]	Non-profit/advocacy	73
Landowner	42	Flood plain manager	48	Hunting/fishing	73
Farmer	44	Local official	62	Concerned citizen	64
Coal mining	62	University scientist	57	Other	72
B. Level of involvement in streams and wetland related issues:					
Very involved	61(%)				
Involved	55				
Somewhat Involved	54				
Not Involved	63				
C. Level of awareness or knowledge of streams and wetland issues					
Yes	57(%)				
No	60				
D. Watershed region in which respondent worked or is most familiar:					
Kentucky River	64(%)	Licking River[b]	59		
Salt River[b]	47	Green/Tradewater[c]	46		
Upper Cumberland River	64	Four Rivers Basin	40		
Big/Little Sandy & Tygarts	50	Entire state	63		
Ohio River	53	Other	59		

[a] Percentages not reported due to low numbers.
[b] Includes minor Ohio River Tributaries.
[c] Includes major Ohio River Tributaries.

sewer overflows and straight pipes as very serious threats to streams and wetlands (Table 4). While rating sewer over flows and straight pipes as high priority, people holding other job positions were significantly less likely than those involved in environmental advocacy or hunting/fishing to rate sewer overflows and straight pipes the same way (χ^2 = 83.50, df = 54, P = 0.006). On the other hand, level of involvement (χ^2 = 10.1, df = 9, P = 0.34) and awareness of streams and wetlands information (χ^2 = 0.38, df = 3, P = 0.95) were not significant factors in explaining views on sewage and straight pipes. There were, however, some differences among watershed regions, (χ^2 = 54.90, df = 27, P = 0.001) with those working or living in the Kentucky River Basin more likely than those in the Salt, Green and Tradewater, and Four Rivers basins to rate the impacts of raw sewage as a very serious impediment to streams and wetlands.

Coal and energy development. Job position (χ^2 = 165.90, df = 54, P < .001), watershed region (χ^2 = 38.80, df = 9, P < 0.001), as well as level of involvement (χ^2 = 62.40, df = 27, P < 0.001) were each significant in explaining differences in stakeholder perceptions on the effects of coal and energy on Kentucky's water resources (Table 5). Among job positions, university scientists, environmentalists, and those involved in non-profit/advocacy in comparison to landowners, local officials, and those involved in coal mining rated the threats associated with coal and other forms of energy development as very serious. While awareness was not a significant factor (χ^2 = 0.38, df = 3, P = 0.95), level of involvement was. Those reporting themselves as "very involved" in streams and wetlands related issues were more likely than those reporting themselves as not that involved to underscore the potential negative effects of the energy industry on streams and wetlands. There also were differences among the watershed region of respondents that listed coal and energy development as a very serious impact on streams and wetlands. Those in the Licking River and Kentucky River basins and those whose work covered all of Kentucky underscored the threats associated with coal mining more so than those stakeholders in the Big Sandy/Little Sandy/Tygarts, Ohio, Salt, Green/Tradewater, and Four Rivers basin alone.

Residential growth. Among online survey respondents that listed residential growth as a very serious impact, job position or role in

Table 5. Percent of respondents reporting coal and energy development as a "very serious impact" by job position (A), level of involvement (B), level of awareness (C), and by watershed region (D).

A. Primary role or job position					
State/federal employee	44(%)	Environmentalist	67	Private engineer	46
Permit holder	–[a]	Outreach and education	45	Private attorney	–[a]
Developer	–[a]	Water works professional	–[a]	Non-profit/advocacy	69
Landowner	28	Flood plain manager	21	Hunting/fishing	50
Farmer	16	Local official	22	Concerned citizen	56
Coal mining	0	University scientist	63	Other	59
B. Level of involvement in streams and wetland related issues:					
Very involved	61(%)				
Involved	38				
Somewhat Involved	35				
Not Involved	42				
C. Level of awareness or knowledge of streams and wetland issues					
Yes	43(%)				
No	41				
D. Watershed region in which respondent worked or is most familiar:					
Kentucky River	47(%)	Licking River[b]	52		
Salt River[b]	34	Green/Tradewater[c]	37		
Upper Cumberland River	18	Four Rivers Basin	38		
Big/Little Sandy & Tygarts	38	Entire state	61		
Ohio River	29	Other	49		

[a] Percentages not reported due to low numbers.
[b] Includes minor Ohio River Tributaries.
[c] Includes major Ohio River Tributaries.

relation to streams and wetlands was not a significant factor (χ^2 = 66.40, df = 54, P = 0.12), although university scientists were more likely to view it as a priority concern than were other stakeholder groups (Table 6). Likewise, awareness was not a significant factor (χ^2 = 6.60, df = 3, P = 0.08). Yet, those very involved in streams and wetlands issues were significantly more likely to express concern over the impacts of residential growth than those less involved (χ^2 = 22.50, df = 9, P = 0.007). Watershed region was also significant (χ^2 = 47.80, df = 27, P = 0.008) with those in the Kentucky, Licking and Big Sandy/Little Sandy and Tygarts River Basins more likely to identify the impacts of residential growth as a high priority issue of concern, as opposed to stakeholders in other watersheds.

Interview Results

The following qualitative review of phone and panel interviews provided additional insight into the three priority impacts and, in particular, illustrated the anticipated conflict between resource users and other groups when it came to issues surrounding the extraction of coal and its subsequent effects on water resources.

Coal and energy development. The challenges and conflicts posed by coal and energy development were discussed, often at some length, by stakeholders in their telephone interviews and with steering committee members during their advisory sessions. Survey results showed differences among stakeholder groups in regards to the impacts of coal and energy on Kentucky's streams and wetlands. Stakeholders associated with the coal industry, farmers, local officials, and flood plain managers were less likely to identify coal and energy development as negative impacts. Whereas, environmentalists, those involved in non-profit advocacy work and university scientists tended to view coal and energy development as having negative impacts on streams and wetlands of Kentucky. Many stakeholders and steering committee members recognized the balancing act and trade-offs of energy production and protecting water resources in the intensive coal mining regions of both eastern and western Kentucky. This balance, for many, posed one of the greatest challenges to stream and wetlands conservation within the state. As one state agency representative said: "I think another daunting

Table 6. Percent of respondents reporting residential growth as a "very serious impact" by job position (A), level of involvement (B), level of awareness (C), and by watershed region (D).

A. Primary role or job position					
State/federal employee	37(%)	Environmentalist	39	Private engineer	41
Permit holder	–[a]	Outreach and education	46	Private attorney	–[a]
Developer	–[a]	Water works professional	–[a]	Non-profit/advocacy	48
Landowner	26	Flood plain manager	21	Hunting/fishing	43
Farmer	29	Local official	31	Concerned citizen	39
Coal mining	27	University scientist	61	Other	45
B. Level of involvement in streams and wetland related issues:					
Very involved	48(%)				
Involved	38				
Somewhat Involved	31				
Not Involved	31				
C. Level of awareness or knowledge of streams and wetland issues					
Yes	39(%)				
No	26				
D. Watershed region in which respondent worked or is most familiar:					
Kentucky River	41(%)	Licking River[b]	45		
Salt River[b]	35	Green/Tradewater[c]	37		
Upper Cumberland River	25	Four Rivers Basin	32		
Big/Little Sandy & Tygarts	40	Entire state	36		
Ohio River	30	Other	26		

[a] Percentages not reported due to low numbers.
[b] Includes minor Ohio River Tributaries.
[c] Includes major Ohio River Tributaries.

challenge out there is with resource extraction. We all want our electricity. Coal is a very important source for that, but it's also one of the largest footprints on our landscape as far as water quality is concerned, especially now with some of the practices, the mountaintop or near-mountaintop removal, where there's lots of valley fills, hollow fills taking place because that fills up those headwater streams. You get the leaching of the groundwater then into the surface water. That's coming through all those geologic strata that, at one time, was capped, and that was groundwater. So, now you have all these ions and these metals, total dissolved solids that are being leached now into the surface water. That is a legacy effect that's probably going to be with us for hundreds of years."

Others mentioned what they perceived as the nearly irrecoverable losses to streams and wetlands from coal mining. One advisory member commented, "But when you look at it from an environmental viewpoint there are very little good things about coal, especially now with mountaintop removal, where they just flatten it and take the tops off of mountains, and with filling in the small tributaries at the tops of the mountains." For this advisory committee member who is also a university scientist, the industry argument that filler streams are basically drainage ditches that only fill after it rains and therefore are not streams subject to protection under the Clean Water Act was unfounded. As he recounted, "Those streams are the feeder streams to all of the rivers and all of the water in Kentucky. If you mess up the feeder streams, then you are messing up everything. So, coal is certainly a huge, huge challenge."

Another agency official working in fish and wildlife management also identified mining as the major threat to streams and species diversity in Kentucky. He discussed how he reviewed about two mine permits per day and reflected on how those operations will have long-lasting impacts on streams because they alter water quality and increase conductivity from heavy metals that will be harmful to sensitive species. During interviews, steering committee members and stakeholders expressed concerns that coal mining and mountaintop removal practices have negative impacts on water quality as well as result in the loss of stream habitat and aquatic species. One stakeholder acknowledged the conflict between the twin demands for energy and water

and described the need to mine more responsibly: “Mining minerals is a big problem; we all know that; we all know what’s going on in eastern Kentucky. That’s not going to stop tomorrow. We need the energy; the energy is feeding the room that we’re in right now to have this meeting. So while we have to have it, we need to try to focus on doing that within the most responsible means necessary.”

Although most saw coal mining as a major threat to Kentucky’s streams and wetlands, some also pointed out that the coal industry was better regulated than other types of industry and development. As one engineer stated, “I feel that coal mining is regulated as much as need be at this time. However, the encroachment of residential growth, logging operations, and highway construction are not regulated to the extremes that mining has been subjected to. With the exception of coal mining, these other issues need to be regulated more to provide additional protection for our streams and wetlands.” Others involved in mining reclamation (in this case, another university scientist) were of the opinion that landscapes could be partially restored and recovered during post mining reclamation, “…there seems to be a mindset that, if you mine, you permanently destroy the land and the streams and you bury the streams, and some of that is correct. But I don’t agree that you completely destroy the land because since 1996 there are demonstration sights where they are doing this loose dump soil and growing high value hardwood trees very successfully.”

Residential growth. Although mountaintop removal is currently a politically “hot topic” in Kentucky, residential growth and population increase were also frequently cited. As one steering committee member said, “Probably the biggest challenge of all is that we keep expanding as a population and moving out. In just the last few decades, what once was land covered by large expansive farms is now land dominated by shopping centers, housing subdivisions, and a plethora of buildings. No longer is water able to move freely in and out of these places. There are no longer open fields where when it rains the water can be soaked up. This is so detrimental to a stream.”

Another steering committee member made a similar comment, “One of the biggest challenges is how Kentucky is always growing and developing. This is good for stimulating job growth and the economy. However, growth tends to undermine or hurt natural resources. Streams and watersheds need to be incorporated in the continuing growth and given an equal value in that growth.” He went on to comment on the current stream mitigation program that requires payment into a restoration fund for development impacts to streams, “It would be nice to not have to say ‘we are restoring this or taking care of this impairment’ but to be able to say ‘we did a great job here; this resource is in such great shape still.’ That is the biggest challenge: to grow smart.” In short, in our interviews with stakeholders, the impact associated with economic growth and development was seen as a major hurdle to streams and wetlands protection, and as with coal mining, many noted the inherent dilemma between development and environmental protection. One, for example, noted that as we “build more we need more natural resources,” which is “definitely a barrier to restoring anything.”

Sewer overflows and straight pipes. When asked about current efforts to restore and conserve Kentucky’s streams and wetlands, many stakeholders answered that such efforts were “fairly limited.” They cited straight pipes as the “most serious problems that are not being addressed.” Yet, they also recognized, that straight pipes, as with coal mining and residential growth, were more difficult to confront than, as one said, “keeping cattle out of a stream.” One advisory member said, “This is a really, really tough thing to figure out. The reason is because a lot of these homes are up in the hollows. The soil is not good enough for septic fields. The houses are too far apart to make it economically feasible to have sewage treatment plants, or even packaged treatment plants, so the alternative that the people have is straight pipes. Of course, we know that that’s not good for any of us. So, that’s a really difficult problem.”

Hunters, fishermen, and those who spend recreational time in streams and wetlands were most likely to rate sewage as a priority impact. One sportsmen, also a long haul truck driver, commented, “We have seen all manners of waterways and water problems across this great land. We have come to believe that

Kentucky (especially eastern Kentucky) has some of the nastiest waterways we've ever seen… it makes me ashamed to look at our waterways…" Another university scientist, who also spends much time in the field conducting bio-assessments, relayed this account: "A few years ago, this is very gross, I was doing some work in eastern Kentucky. One of my graduate students and I were sampling in this area. They were going to put a gas pipeline in, and that's what the project was about. But we were sampling in this stream that was 20 feet from the front door of this house. These kids were playing in the stream there and the yard. We took nets and went through there. There were things like tampons, condoms, and raw sewage that were coming up in the net. It took us about 30 minutes and a couple of hauls, and I said, 'We're getting out of here. This is a dangerous situation.'"

When online survey respondents were asked to rate the most serious threats to Kentucky's streams and wetlands, aggregate percentages showed sewer overflows and straight pipes (57%) of greater concern than coal and energy (43%) and residential growth (37%). The differences in percentages as well as the interview findings suggest that, in next phase planning, major emphasis should be placed on the impacts of sewer overflows and straight pipes as a priority issue in the protection of our state's water resources. (Some important recommendations and insights into better protection of Kentucky's water resources from sewage, straight pipes, coal mining and residential growth are provided by stakeholders and steering committee members in Section 4 of the 2009 first phase Streams and Wetlands Conservation Plan and can be found online at: http://www.water.ky.gov/permitting/wqcert/.)

CONCLUSIONS

Conservation planning of our nation's water resources has been encouraged by the EPA through providing Wetland Program Development grants to states and tribes. These state-level planning processes have been efforts at forestalling the continued loss and degradation of our nation's streams and wetlands. State planning processes have evolved, and the EPA now encourages all states to apply watershed co-management methods in the conservation planning and protection process. Soliciting the input of various groups to encourage buy-in and participation in the regulatory process and in outreach and education programs has become a common practice in natural resource management. The research on co-management shows that such participatory methods can generate new forms of knowledge and a better understanding of the conflicts and impacts facing our resource base. Knowledge generated from the "ground-up" can assist planners and regulators in developing more sustainable best management practices. Consequently, co-management methods are now routinely applied in devising strategies for environmental protection and natural resource management.

Among states, the methods applied to solicit stakeholder input and participation has varied with each new case or impending resource conflict. For stream and wetlands conservation planning, the Kentucky process is a first effort at replication. We have repeated much of the research design and used research instruments similar to those used by the Montana Wetland Planning Council. The conservation planning process in Kentucky, as in Montana, used a steering committee, telephone interviews, and online surveys to gather feedback into the initial development of its stream and wetlands conservation plan. Unlike Montana, this recent planning process marked Kentucky's first effort. Co-management watershed models are often referred to as "iterative" processes, whereby planning and implementation occur in a fluid manner requiring constant feedback from stakeholders and other knowledgeable participants. This iterative process reflects the complexity of managing scarce resources to meet complicated socio-economic demands and the need for balance, flexibility, and responsiveness in resource management was highlighted in the comments of our steering committee members as well as in our other stakeholder interviews. Everyone agreed, at least, that there are conflicts between economic growth and resource protection; this shared view perhaps can motivate competing stakeholders to participate in Kentucky's second phase of streams and wetlands conservation planning.

Along with the interview findings, our surveys showed some differences in opinion among stakeholders regarding the rank order of major threats to Kentucky's water resources. The coal mine sector and local government representatives took a different perspective than the university scientists and environmentalists concerning the impacts of coal and energy development on our streams and wetlands. This seems to reinforce the idea that there is an inherent conflict between economic development and environmental protection. However, our findings also showed some common agreement among stakeholders on the major challenges facing stream and wetland protection. Specifically, they agreed that resource management processes were complicated and potentially conflicting; they agreed that sewage treatment/straight pipes, coal mining, and residential growth are the primary impacts of concern to the state of Kentucky; and they all recognized the importance of protecting Kentucky's wetlands and streams. As a result of this strong agreement on the top three impacts of concern, we feel confident in recommending that future planning, policy development, and implementation of water resource management, should focus on sewage and straight pipes, coal and energy, and residential growth. Many advisory members and stakeholders provided cogent recommendations regarding needed improvements in infrastructure, outreach, education, and research as well as regulations on each of these fronts. Recommendations and possible strategies need to be brought to the table and discussed in future planning and implementation stages.

Overall, the research and the first phase planning process reinforce EPA's mandate in soliciting stakeholder input in conservation planning and more specifically, demonstrates a sound approach to co-management methods through the application of standard social scientific methods in gathering stakeholder views and opinions. The methods first devised in Montana, then applied here, may have some application in other states in generating new knowledge and in identifying the major challenges to stream and wetlands protection based upon the opinions and positions of various stakeholders. Watershed co-management methods have become standard practice in natural resource protection and conservation and are continuing to evolve into standard tools for identifying priority impacts of concern and in devising best management strategies to use and protect resources more sustainably.

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A Field Guide to Kentucky Field Stations Available for Education and Research

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ABSTRACT

We conducted a survey of Kentucky colleges and universities to determine the number of field station sites available for research, educational, and outreach activities. As a first attempt, we were able to locate and provide basic data for 23. Sites range from thousands of acres to just a few. Some have full, year around research and education programs, while others are largely undeveloped. Existing sites are located primarily in the eastern half of the state with only 4 in the western portion, thus some ecoregions have several while others have none. Although not directly surveyed, website addresses are given that connect to more than 200 state and federal natural areas in Kentucky. It is our hope that the information presented here will stimulate the use of the State's field station sites and point out the needs for acquiring and developing others.

KEY WORDS: Field stations, natural areas, field research, outdoor education, outreach, biological diversity, land acquisition

INTRODUCTION

"Biological field stations provide living libraries and outdoor laboratories for students, researchers, and the general public interested in the environment. They vary greatly in form and purpose, and include both marine laboratories whose focus is offshore, as well as terrestrial (inland) reserves dedicated to protecting key ecosystems" -James Kirchner, University of California, Berkeley.

Natural areas serve many important functions, including reserves of biological diversity, means to determine when and how landscapes have changed because of human activities or species invasions, sites for scientific research and monitoring, PK-16 environmental education, interdisciplinary collegiate education, and as retreat sites for humans to escape their human-dominated landscapes. Thus, they are invaluable to understanding and maintaining large-scale diversity, ecosystem processes, and ecosystem services (see Abernathy et al. 2010 for a comprehensive review of Kentucky landscapes and biodiversity). One category of natural areas is "field stations" where there is active pursuit of research and educational goals in natural settings. Information on the existence or locations of field stations is often more difficult to find than that for "natural areas" in general because they most often are associated with colleges and universities.

The Organization of Biological Field Stations (OBFS, website www.obfs.org) provides a listing of field stations throughout North and Central America. Stations included are those that have (or had) joined the organization. Obviously it is not inclusive of all existing field station sites. As of this writing, there were 332 field stations and marine labs listed at OBFS. Of these, 302 are located in the US. California and New York combined have 60+ listed stations. In states surrounding Kentucky, 14 are listed for Illinois, 8 for Ohio, 4 for Indiana, and 1 for Tennessee. The OBFS Kentucky listing of 4 includes the Hancock Biological Station, Lilley Cornett Woods Appalachian

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Table 1. Descriptive data for field stations associated with Kentucky colleges and universities.

Map #	Field area name	College or university affiliation	Website	Primary contact
1	Hancock Biological Station	Murray State University	www.murraystate.edu/hbs	David White
2	Owensboro Community and Technical College Natural Area	Owensboro Community and Technical College	None	Micah Perkins
3	Upper Green River Biological Preserve	Western Kentucky University	greenriver.wku.edu	Ouida Meier
4	Bernheim Arboretum and Research Forest	Isaac W. Bernheim Foundation	www.bernheim.org	Andrew Berry
5	The Horner Bird and Wildlife Sanctuary[a]	University of Louisville	www.astro.louisville.edu/moore/horner/index.html	Ronald Fell
6	Ohio River Experimental Station	University of Louisville	None	James Alexander
7	Clay Hill Memorial Forest	Campbellsville University	www.clayhillforest.org	Gordon Weddle
8	Hoffman Silvicultural Reserve	Campbellsville University	None	Richard Kessler
9	KSU Environmental Education Center	Kentucky State University	www.ksuenvironmental.org	William Stilwell
10	Asbury Natural Area	Asbury College	www.asbury.edu/majors/naturalsciences/facilities/trails	Larry Olsen
11	Maywoods Ecological and Educational Laboratory	Eastern Kentucky University	www.naturalareas.eku.edu	Melinda Wilder
12	St. Anne Wetlands Research and Education Center	Campbell Conservancy	www.stannewetlands.org	Rebecca Kelley
13	Canoe Creek Preserve	University of Kentucky	None	John Cox
14	Griffith Woods[b]	University of Kentucky	None	John Cox
15	Thomas More College Biology Field Station	Thomas More College	www.thomasmore.edu/fieldstation	Chris Lorentz
16	EKU Ecological Restoration Area	Eastern Kentucky University	None	David Brown
17	Berea College Forest	Berea College	www.berea.edu/forestry	Clint Patterson
18	University of the Cumberlands property	University of the Cumberlands	None	Todd Yetter
19	Glimcher Wetlands	Morehead State University	None	Allen Risk
20	Robinson Center for Appalachian Resource Sustainability	University of Kentucky	www2.ca.uky.edu/rcars	David Ditsch
21	Robinson Forest[b]	University of Kentucky	www2.ca.uky.edu/rcars	David Ditsch
22	Lilley Cornett Woods Appalachian Ecological Research Station	Eastern Kentucky University	www.naturalareas.eku.edu	Melinda Wilder
23	Francis Forest	Big Sandy College Education Foundation	None	Tom Vierheller

[a] Moore Observatory is located at The Horner Bird and Wildlife Sanctuary and available with permission from John Kielkopf (kielkopf@louisville.edu).
[b] Areas associated with University of Kentucky (UK) are also Kentucky Wildlife Management Areas. Robinson Forest is owned by UK, and Griffith Woods is owned by the state of Kentucky.

Ecological Research Station, Robinson Forest, and the Upper Green River Biological Preserve. Only Hancock Biological Station has detailed information associated with it on the OBFS website because it is Kentucky's only active member station. The lack of easily available information on the remaining Kentucky stations and the potential that many more "field station" sites exist led us to inquire about additional sites available at Kentucky colleges and universities, non-governmental organizations (NGOs), and state and federal agencies that share common goals of promoting environmental understanding through research, education, and outreach.

We focused here on using a survey to determine availability of educational and research facilities at the field stations and then making survey results available to the scientific and educational communities. We were most interested in field stations associated with Kentucky colleges and universities but have included references to sites owned by state and federal agencies and NGOs. An

Table 1. Extended.

Email	Counties	Date founded	Size (acres)	Ecoregion
david.white@murraystate.edu	Calloway	1966	100	Interior Plateau
micah.perkins@kctcs.edu	Daviees	1991	18.5	Interior River Valleys and Hills
ouida.meier@wku.edu	Hart	2001	1200	Interior River Valleys and Hills
aberry@bernheim.org	Bullitt	1929	14,592	Interior Plateau
rfell@louisville.edu	Oldham	1960	200	Interior Plateau
jealex01@louisville.edu	Oldham	2002	4	Interior Plateau
gweddle@campbellsville.edu	Taylor	1996	158	Interior Plateau
rkkessler@campbellsville.edu	Taylor	1998	20	Interior Plateau
william.stilwell@kysu.edu	Henry	2005	307	Interior Plateau
lolsen@asbury.edu	Jessamine	1990	340	Interior Plateau
melinda.wilder@eku.edu	Garrard, Rockcastle	1973	1740	Interior Plateau
kelleyr1@nku.edu	Campbell	2009	100	Interior Plateau
jjcox@uky.edu	Garrard	2010	280	Interior Plateau
jjcox@uky.edu	Harrison	2004	410	Interior Plateau
chris.lorentz@thomasmore.edu	Campbell	1967	50	Interior Plateau
david.brown@eku.edu	Madison	2010	20	Interior Plateau
clint.patterson@berea.edu	Jackson, Madison, Rockcastle	1898	8400	Western Allegheny Plateau
todd.yetter@ucumberlands.edu	Whitley	1933	8000	Central Appalachians
a.risk@moreheadstate.edu	Rowan	1989	30	Western Allegheny Plateau
dditsch@uky.edu	Breathitt	1925	70	Central Appalachians
dditsch@uky.edu	Breathitt, Knot, Perry	1923	14,600	Central Appalachians
melinda.wilder@eku.edu	Letcher	1969	554	Central Appalachians
thomas.vierheller@kctcs.edu	Floyd	1997	300	Central Appalachians

additional goal was to highlight where ecoregion gaps in field station distributions exist across the state and to point out the need to acquire and protect more natural areas for use in research, education, and outreach. Further, knowledge of the range of Kentucky field sites for research, education, or outreach is valuable in understanding the array of local and regional environmental resources available.

MATERIALS AND METHODS

We first contacted appropriate individuals (usually in biology departments) at each of the Kentucky community colleges, four-year colleges, and universities to determine what stations existed. We then created a survey designed to inventory environmental field resources and facilities where sites had been identified. The survey was based on one presently used by OBFS. Eventually we widened the scope to include selected natural areas currently with and without field station facilities. Our rationale was to provide a more complete listing of Kentucky's research and educational natural areas regardless of there being any developed facilities as a means to promote these sites for future development as field stations. Survey data for individual sites

Table 1. Extended.

Lodging capacity	Classroom capacity	Laboratory capacity	Boat access	Parking	Availability
Cabins	110	5 Labs	Yes	Yes, Bus	Year round
0	70	6	No	Yes, Bus	Year round
House (12)	1 classroom	0	Yes	Yes, Limited bus	Year round
0	3 classrooms, 140 students	0	No	Yes, bus	Year round
0	0	0	No	Yes	Year round; Not open to the public
0	0	0	Yes	Yes	May–October; Not open to public
Tent Space (5)	125	25	No	Yes, Bus	Year round
House (12)	16	0	No	Yes, Bus	Year round (by appointment)
Tents	4 platforms	0	No	Yes, Bus	Spring-Fall
Summer dorms	Summer on campus	Summer on campus	No	Yes	Year round
Dorm (40)	90	0	Yes	Yes, Bus	April 1–October 31
0	0	0	No	Yes	Year round
0	0	0	No	Yes	Year round
2 Cabins	Large barn	0	No	Yes, Bus	Year round (by appointment)
Dorm and Cabin (20)	30	35	Yes	Yes, Bus	Year round
0	0	0	No	Yes	Year round
0	On campus	On campus	Yes	Yes	Year round
0	No	No	No	Yes	Year round (by appointment)
0	0	0	No	Yes, Limited	Year round
0	7 classrooms	0	No	Yes, Bus	Year round
Cabins (50)	45	0	No	Yes, Bus	Year round
0	40	0	No	Yes, Bus	April 1–October 31
0	0	0	No	Yes	Year round

are available upon request to corresponding author. Field areas associated with state and federal agencies and NGOs were not surveyed, but we have provided summary information and website links for these areas.

RESULTS AND DISCUSSION

The survey identified 23 biological stations associated with colleges/universities and foundations in Kentucky that are available for research and/or education (Table 1; Figures 1, 2). Sizes range from over 14,500 acres (Robinson Forest) to 4 acres (Ohio River Experimental Station). The oldest is the Berea College Forest established in 1898, while nearly a third have existed for less than a decade. Unlike NGOs and governmental agencies that target acquisition of specific lands, field stations associated with universities usually are serendipitous resulting from land gifts set aside by donors (most often private) with the goals of creating research or educational areas. As such they often begin with no educational classroom space or the capacity to house researchers. This appears to be true for at least half of the field sites identified with Kentucky universities. More than 50% of the identified stations have some

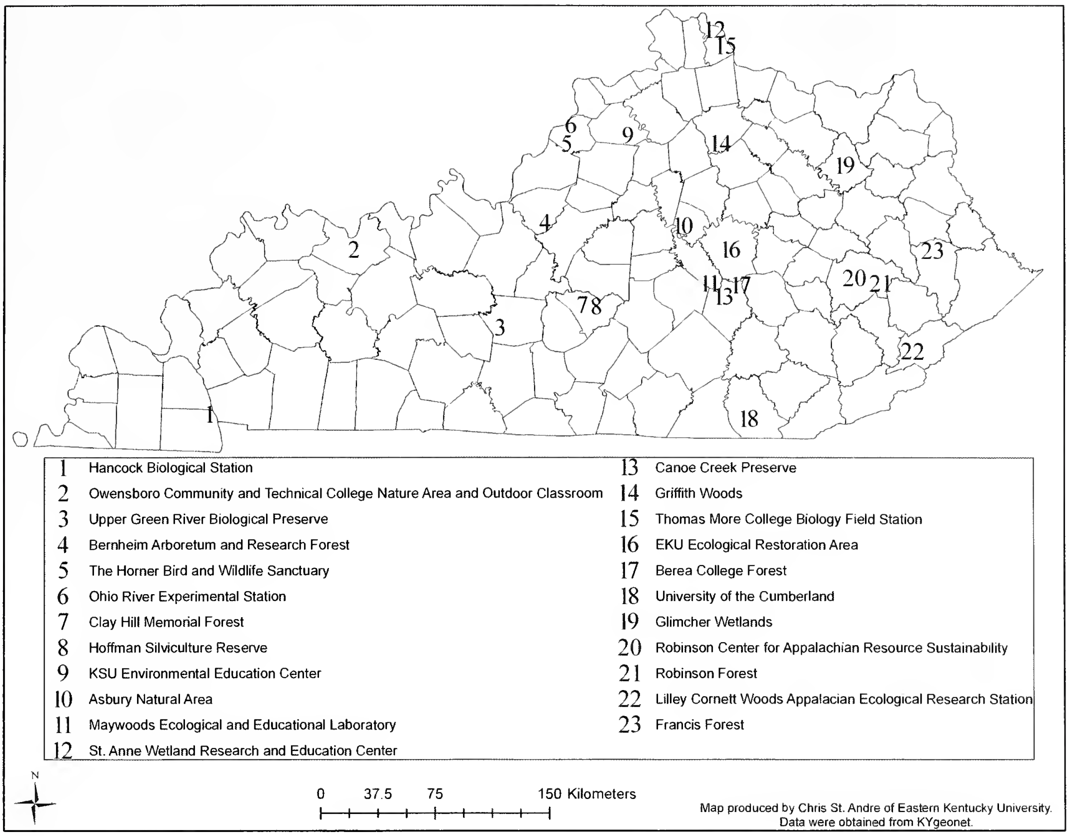

Figure 1. County map of Kentucky depicting research and educational natural areas associated with Kentucky community colleges, colleges, and universities. Areas are numbered in order from west to east.

type of classrooms available, while only a third have any housing. Only three have dedicated laboratory space. Most of the field stations are available for research and education the year around, but permission of the directors is requested or required. Only the Horner Bird and Wildlife Sancturary and Ohio River Experimental Station are not open to the general public.

Throughout Kentucky the majority of the field stations are found in the central and eastern portion of the state. Only Hancock Biological Station is located at the western end of the state, thus many large geographic gaps exist (Figure 1). Additionally, field stations are located in only 4 of Kentucky's 7 level-3 ecoregions (Figure 2). The stations are located predominately in the Interior Plateau (14) and Central Appalachian (5) ecoregions, while 2 are in Western Allegheny Plateau and 2 in the Interior River Valleys and Hills ecoregions (Figure 2). No field stations associated with colleges and universities are located in the Mississippi Alluvial Plains, Mississippi Valley Loess Plains, or Southwestern Appalachian ecoregions. In general, many ecological and geographic regions are not yet represented.

Natural areas associated with colleges and universities have been acquired in a variety of ways. Kentucky has two Land Grant colleges, the University of Kentucky and Kentucky State University. Through the Morrill Act of 1862 and the revision in 1890, these colleges received federal lands to be put to use as the institution focused on agriculture and mechanical arts training for its students. The land could be used for the benefit of the university in any way deemed appropriate by the State. Much of the land given for University of Kentucky was sold. Most of Kentucky State University's land is devoted to agriculture and aquaculture programs. The primary source of

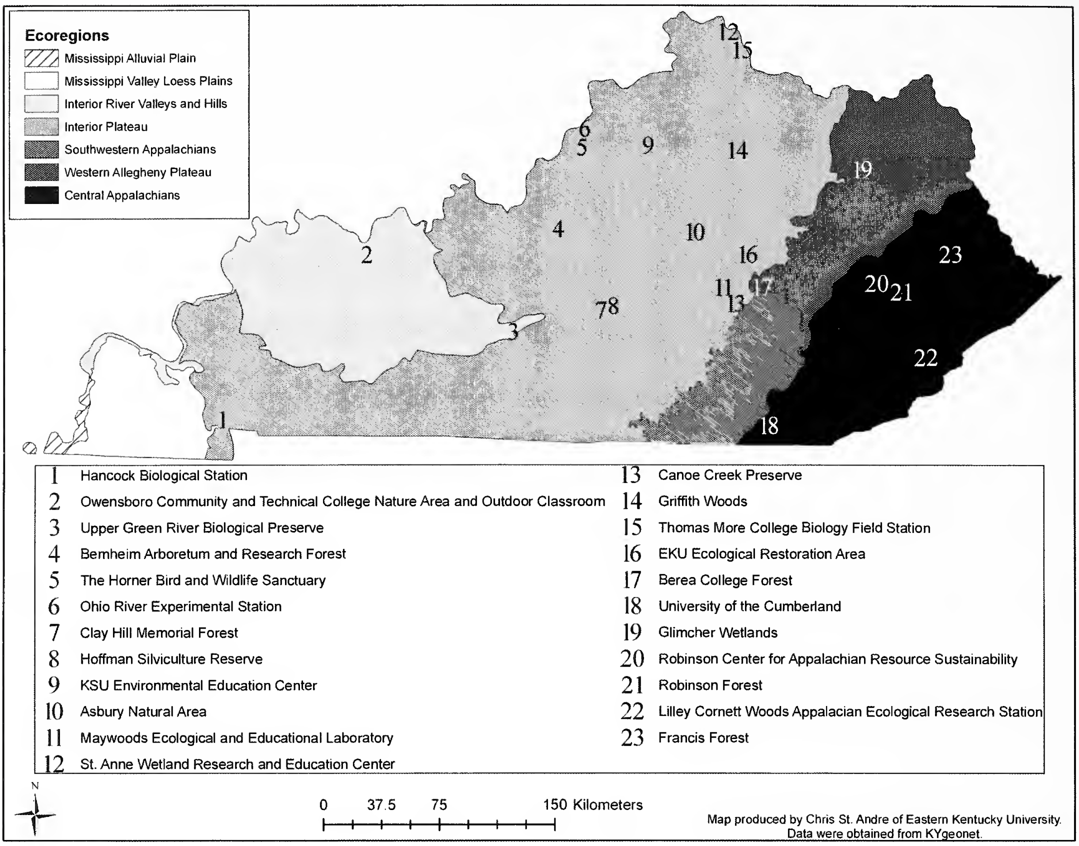

Figure 2. Level 3 ecoregions map of Kentucky depicting research and educational natural areas associated with Kentucky community colleges, colleges, and universities. Areas are numbered in order from west to east.

funding for Kentucky's field stations, as noted above, is through donation of land from the private sector. A good example of this is Robinson Forest, donated by E. O. Robinson in 1923.

The donation of lands sometimes comes with restrictions as to its use and/or sale. For example, the Kentucky State University's Environmental Education Center specifically states that its programs and facilities will be designed to accommodate a variety of disabled students. Some universities have been able to purchase tracts of lands outright. Others have worked with land trusts such as the Kentucky Heritage Land Conservation Fund Board (heritageland.ky.gov) or the Kentucky Natural Lands Trust (knlt.org) to acquire ecologically important tracts of land that would benefit their research and education programs. Other acquisition methods include conservation easements or land transfers with some governmental agency at the county, state, or national level. For example, the Hancock Biological Station is located on both university and Tennessee Valley Authority (TVA) lands. The TVA portion is to be used by Murray State University as long as a field station exists there.

One goal of this paper is to serve as a request for faculty, staff, and students at Kentucky colleges and universities to work with administrators, colleagues, alumni, and granting agencies to garner support for the establishment of natural areas and aspire to create and fund field station facilities where appropriate. Natural areas associated with colleges and universities tend to be more accessible to scientists and educators, especially if research and educational facilities are available. In addition to serving human needs, field stations need to be properly selected and managed to maximize local and regional

Table 2. Government agencies and non-governmental organizations that own or manage natural areas and field stations in Kentucky.

Organization	# of areas	Website
State Agencies		
Kentucky Department of Fish and Wildlife Resources	80[a,b]	http://fw.ky.gov/kfwis/wmaguide.asp
Kentucky Division of Forestry	9[c]	http://forestry.ky.gov/Kentuckysstateforests
Kentucky National Guard	1[d]	http://fw.ky.gov/kfwis/arcims/wma.asp?strId=9115
Kentucky State Nature Preserves Commission	54[b]	http://naturepreserves.ky.gov/naturepreserves/Pages/statewide_snpsna.aspx
Kentucky State Parks	51[e]	http://parks.ky.gov/findparks
Federal Agencies		
U.S. Army	3[f]	http://www.campbell.army.mil http://www.knox.army.mil/ http://fw.ky.gov/kfwis/arcims/wma.asp?strId=9088
U.S. Fish and Wildlife Service	3	http://www.fws.gov/clarksriver http://www.fws.gov/reelfoot http://www.fws.gov/frankfort/
U.S. Forest Service	2[g]	http://www.fs.fed.us/r8/boone/index.shtml http://www.lbl.org
U.S. National Park Service	4	http://www.nps.gov/state/ky
Non-governmental Organizations		
The Nature Conservancy	23	http://www.nature.org/wherewework/northamerica/states/kentucky/preserves
The Audubon Society	1	http://buckleyhills.org/about.html

[a] KDFWR website includes wildlife management areas and natural areas associated with other agencies. Only those considered wildlife management areas are included in our count. Other sites are included in count and website of other agencies above.
[b] Four state-owned sites are both wildlife management areas and state natural areas and are included in the count and websites of KDFWR and KSNPC.
[c] The division owns and manages nine state forests totaling 41,044 acres.
[d] Hidden Valley Training Area does not have a website.
[e] Some state parks do not have associated natural areas.
[f] Bluegrass Army Depot does not have a website.
[g] The Daniel Boone National Forest is 707,00 acres on the Cumberland Plateau of eastern Kentucky. Multiple agencies manage wildlife and forests at and Between The Lakes National Recreation Area, including KDFWR.

biological diversity (Muller and Maehr 2000; Schuhmann 2008).

As humans continue to encroach on the natural landcape, the need to preserve and understand the ecology and functions of natural areas increases. Methods exist for prioritization of establishing natural areas, and many of these seek to maximize preservation of ecosystem and species diversity (e.g., Muller and Maehr 2000; Vora et al. 2007). In Kentucky, protection of natural landscapes is accomplished primarily through state and federal agencies and non-government agencies. Kentucky has 195 state and 12 federally owned field areas that represent potential sites for research and education, and at least 24 are owned by NGOs (Table 2). However, the vital role played by field stations and natural areas associated with universities and colleges, although many fewer, should not be undervalued. When we first discussed the idea of creating a "field guide" to Kentucky's field stations, we really had no idea how many existed. We were very pleased to locate 23, nearly six times more than listed on the OBFS website, and we recognize that more may exist. This would indicate that the numbers of field stations in neighboring states and indeed across the country also is greatly underestimated. It is hoped that researchers and educators will take advantage of the field opportunities located in Kentucky, support their development, and work to establish new sites.

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Witherington, and Mike Wourms. GIS data were obtained via the Kentucky Geography Network.

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Abstracts of Some Papers Presented at the 2010 Annual Meeting of the Kentucky Academy of Science

Edited by Robert J. Barney

AGRICULTURAL SCIENCES

Leaf Stomatal Density Variation in Eleven Pawpaw Cultivars. SHERI B. CRABTREE*, KIRK W. POMPER, KESI NEBLETT, and SIERRA SKAGGS, Community Research Service, Land Grant Program, Kentucky State University, Frankfort, KY 40601.

The pawpaw [*Asimina triloba* (L). Dunal] is a native tree fruit found in most of the eastern U.S. As the satellite site for the USDA National Clonal Germplasm Repository for *Asimina* species, goals of the KSU pawpaw research program include description and classification of pawpaw germplasm. With summer droughts and lack of water for irrigation often being a challenge for growers, use of drought-tolerant plants is desirable. Plants with fewer stomata on their leaf surfaces are generally better adapted to dry conditions. Drought tolerant pawpaw cultivars have not been definitively identified. The objective of this study was to examine density of stomata in leaves of eleven pawpaw cultivars. Five leaves were collected from eleven different pawpaw cultivars (Shenandoah, Susquehanna, Middletown, Mitchell, NC-1, Overleese, PA-Golden, Sunflower, Taytwo, Wilson, and Wells) at the KSU research farm. Leaf stomata impressions were made using clear fingernail polish and mounted to a microscope slide using adhesive tape. Stomata were counted using a compound light microscope at 400× magnification. Stomatal density varied significantly by cultivar, with Sunflower having the most stomata per mm^2 (387) and Shenandoah (232), Mitchell (221), and Wells (220) the fewest stomata per mm^2. These cultivars could potentially be more drought-tolerant than others due to their low stomatal density.

Genetic Diversity in Five Kentucky Pawpaw Populations Using SSR Markers. YANKUBA BANDA*, JEREMIAH D. LOWE, KIRK W. POMPER, LI LU, and SHERI B. CRABTREE, Land Grant Program, Kentucky State University, Atwood Research Facility, Frankfort, KY 40601-2355.

Pawpaw [*Asimina triloba* (L.) Dunal] is a tree-fruit that is a native understory tree in the eastern region of the United States. The fruit has a rich, unique flavor and pawpaw has great potential as a new fruit crop. Kentucky State University (KSU) in Frankfort, KY is the site for the USDA National Clonal Germplasm Repository for pawpaw (*Asimina*) species, containing over 2000 accessions from 17 different states. Repository research priorities include the evaluation and collection of unique pawpaw selections, or genotypes, for preservation and use in pawpaw breeding efforts. The objective of this study is to evaluate the genetic diversity in five pawpaw populations including one population at the Salato Wildlife Center in Frankfort, KY, three populations at the KSU Environmental Education Center in Henry County, KY, and a Kentucky population of trees grown from seed from trees in Fayette County, KY. Leaves from 20 trees were sampled from each population and DNA extracted using the DNAMITE Plant Kit. Primers B3, B103, and B129 were labeled with FAM and used to amplify PCR-SSR products which were then separated with a 3130 Applied Biosystems capillary electrophoresis system. Genetic relationships were determined using the software program Power Marker. Primers B3, B103, and B129 generated multiple polymorphic alleles at each locus, which ranged from approximately 100 to 350 base pairs in size. The SSR markers generated showed significant genetic variation among the pawpaw populations, indicating these unique populations should be sampled and incorporated into the KSU germplasm collection.

Identification of High Annonaceous Acetogenin Activity in Ripe Fruit Pulp of Advanced Selections of Pawpaw. BRANDEN BELL*, JEREMIAH D. LOWE, KIRK W. POMPER, and SHERI B. CRABTREE, Land Grant Program, Kentucky State University, Atwood Research Facility, Frankfort, KY 40601-2355.

Pawpaw [*Asimina triloba* (L.) Dunal] is a native tree fruit in eastern North America. This plant contains annonaceous acetogenins in fruit and vegetative tissues that display antitumor, pesticidal, antiviral, and antimicrobial activity, with many potentially useful applications. Kentucky State University (KSU) is the site of the USDA Repository for pawpaw species and germplasm evaluation and collection are program priorities. The objective of this study was to identify KSU advanced selections with high acetogenin activity to serve as new sources of biomass for acetogenin extract. About 10 grams of thawed ripe fruit pulp from KSU advanced selections G6-120 and G4-25, as well as the cultivars 'Susquehanna' and 'Sunflower', were extracted with 95% ethanol. The brine shrimp test (BST) was employed to assess acetogenin activity in pulp extracts. Concentrated extract was transferred to vials to correspond to 0, 1, 5, 10, and 100 ppm concentrations with three replicate vials per concentration. Ten brine shrimp larvae, taken 48 h after initiation of hatching in artificial seawater, were added to each vial, and the final volume of each vial was adjusted to 5 ml using artificial seawater. After 24 h, survivors were counted. Brine shrimp mortality was low (3%) in 0, 1, 5, and 10 ppm concentrations. However, at 100 ppm 'Susquehanna' (80%) showed high brine shrimp mortality and 'Sunflower' (55%) low mortality, while G6-120 and

G4-25 both displayed high mortality (100%). These KSU advanced selections have high potential acetogenin activity and could serve as new sources of biomass for acetogenin extract.

Genetic Diversity and Geographic Differentiation in Pawpaw [*Asimina triloba* (L.) Dunal] Populations from Six States as Revealed by SSR Markers. JACOB B. BOTKINS*, JEREMIAH D. LOWE, KIRK W. POMPER, LI LU, and SHERI B. CRABTREE, Land Grant Program, Kentucky State University, Atwood Research Facility, Frankfort, KY 40601-2355.

Pawpaw [*Asimina triloba* (L.) Dunal] is a tree-fruit that is a native understory tree in the eastern region of the United States that is in the early stages of commercial production. Kentucky State University (KSU) in Frankfort, KY is the site for the USDA National Clonal Germplasm Repository for pawpaw (*Asimina*) species, containing over 2000 accessions from 17 different states. Research priorities for the repository include assessment of genetic diversity and collection of unique pawpaw genotypes. The objective of this study is to evaluate the genetic diversity in six pawpaw populations in the KSU-USDA repository orchard (IN-1, IN-2, KY, MD, NY, and WV). These populations will include 10 trees from Washington County, IN (IN-1), 8 trees from Decatur County, IN (IN-2), 23 trees from Tompkins County, NY, 13 trees from Tyler County, WV, 14 trees from Talbot County, MD, and 21 trees from Fayette County, KY. DNA was extracted using the DNAMITE Plant Kit from leaf samples collected from trees in each population. Primers B3, B103, B129, C104, and G119 labeled with FAM were used to amplify SSR products, and products were separated with a 3130 Applied Biosystems capillary electrophoresis system. Genetic relationships among the pawpaw populations were examined using the software program Power Marker. The SSR markers generated showed significant genetic variation among the pawpaw populations. A number of unique genotypes in the populations should be sampled and incorporated into the KSU germplasm collection.

Competition Between Weeds and Primocane Fruiting Blackberries from the University of Arkansas Breeding Program Grown Under Organic Production in Kentucky. JEREMIAH D. LOWE[1]*, KIRK W. POMPER[1], SHERI B. CRABTREE[1], JOHN R. CLARK[2], and JOHN G. STRANG[3], [1]Atwood Research Facility, Land Grant Program, Kentucky State University, Frankfort, KY 40601; [2]Fruit Culture & Breeding, 316 Plant Science Bldg., University of Arkansas, Fayetteville, AR 72701; and [3]Department of Horticulture, N-318 Agricultural Sciences North, University of Kentucky, Lexington, KY 40546.

Primocane fruiting blackberries are attractive to Kentucky growers because they can be grown organically and have the potential to produce a niche-market crop from late summer until frost. In June 2009, a Blackberry Regional Variety Trial was planted at the KSU Research and Demonstration Farm in the certified organic land. This planting contains four replicate blocks of advanced selections of thorny and thornless primocane fruiting blackberries from the University of Arkansas (APF-120T, APF-132, APF-136T, APF-138T, APF-139T, APF-140T, and APF-146T), and the commercially available primocane fruiting blackberry 'Prime Jan'. Selections APF-120T and APF-132 are dwarf selections that do not reach over one meter in height. The objective was to determine if dwarf primocane blackberry selections are able to compete with weeds in plots as effectively as non-dwarf selections when grown organically in Kentucky. A combination of cultivation, hand weeding, flaming, and straw mulch was used for weed control. In August 2010, weed pressure readings (1 = no weed pressure, 10 = extreme weed pressure) were taken by three individuals. Dwarf selections APF-120T and APF-132 displayed significantly more weed pressure (7.8 and 8.1, respectively) than full sized selections APF-146T and 'Prime Jan' (3.4 and 1.4, respectively). Additional weed control strategies will need to be developed to effectively grow dwarf primocane fruiting blackberries organically in Kentucky.

Budding Success and Vigor of Two Cultivars and Eight Kentucky State University Advanced Selections of Pawpaw. KIRK W. POMPER*, SHERI B. CRABTREE, and JEREMIAH D. LOWE, Atwood Research Facility, Kentucky State University, Frankfort, KY 40601.

The pawpaw [*Asimina triloba* (L.) Dunal] is a native tree fruit and is a new high-value fruit crop in Kentucky. Pawpaw fruit have fresh market appeal for farmers' markets, community supported agriculture, and organic markets, as well as processing potential for frozen pulp production. New high yielding cultivars with excellent fruit quality would assist in the development of a pawpaw industry. Kentucky State University (KSU) serves as the National Clonal Germplasm Repository for pawpaw, and germplasm evaluation is an important research priority. Genotypes in the KSU repository orchards that produced high yields and excellent fruit quality have been selected for clonal propagation (budding onto rootstock) and field trials. The objectives of this study were to determine if budding success rate and growth rate of scions would vary by pawpaw selection. In a greenhouse experiment, actively growing one-year-old container grown rootstock, with a range of genetic backgrounds, were budded with KSU-Atwood™ and Sunflower (controls), as well as Hi4-1, H3-120, G4-21, G4-25, G5-23, G6-120, G9-109, or G9-111. At 19 weeks after budding, most selections were budded successfully (75%); however, the selection G4-21 had a poor budding success rate (40%). Most selections displayed excellent vigor (35 cm in height and 14 leaves on average); however, G4-21 (17.7 cm and 11 leaves) and G4-25 (19.7 cm and 9 leaves) displayed poor vigor. Most of the pawpaw advanced selections had similar

budding success and vigor to controls and are excellent candidates for field trials.

Effect of Pigweed, *Amaranthus hybridus*, on Attractancy of Methyl Salicylate-Based PredaLure Lures for Pink Lady Beetle, *Coleomegilla maculata*, and Asian Lady Beetle, *Harmonia axyridis*. JOHN D. SEDLACEK*, DISHAN ROMINE, and KAREN L. FRILEY, Atwood Research Facility, Kentucky State University, Frankfort, KY 40601.

Lady beetles are attracted to flowering plants including species in the aster family such as goldenrods, *Solidago* spp.; button mums, *Chrysanthemum* spp.; daisies, *Chrysanthemum* spp.; and sunflowers, *Helianthus* spp. They also are attracted to odors given off by 2-phenylethanol and methyl salicylate-based lures. Previous laboratory experiments and field experiments conducted by the KSU entomology laboratory using conventionally grown sweet corn demonstrated that PredaLure® is attractive to the pink lady beetle and to a lesser degree the Asian lady beetle. In another field experiment conducted in organically grown sweet corn, PredaLure did not appear to be attractive to these two lady beetle species. The major difference between the two field experiments was that the organic sweet corn plots were covered by at least 80% pigweed while the conventional plots contained very little. This suggested that presence of pigweed could influence attractancy of the lures. Laboratory experiments using an olfactometer were conducted at room temperature to determine if pigweed, *Amaranthus hybridus*, was attractive to the pink lady beetle, *Coleomegilla maculata*, and the Asian lady beetle, *Harmonia axyridis*. Volatiles of pigweed and PredaLure were not attractive to both Asian lady beetle and the pink lady beetle. Asian lady beetle did not respond positively or negatively to pigweed, pigweed + PredaLure or PredaLure alone. However, pink lady beetle was attracted to PredaLure alone, but was repelled by pigweed and by pigweed + PredaLure. Results will be discussed relative to weed presence in agricultural fields and the push-pull hypothesis.

Timing of Primocane Mowing Influences Flowering and Ripening Time in Primocane Fruiting Blackberry Selections in Kentucky. KAREN L. FRILEY*, JOHN D. SEDLACEK, KIRK W. POMPER, JEREMIAH D. LOWE, SHERI B. CRABTREE, and MICHAEL K. BOMFORD, Atwood Research Facility, Kentucky State University, Frankfort, KY 40601.

Primocane fruiting blackberries, such as 'Prime-Jim®' and 'Prime-Jan®', have the potential to produce a niche-market crop for Kentucky growers from late summer until frost. However, fruit size and quality of 'Prime-Jim®' and 'Prime-Jan®' are affected by the environment. Summer temperatures above 85°F can greatly reduce fruit set, size and quality on primocanes. Strategies to delay primocane growth, such as spring mowing of primocanes, could delay flowering and fruit harvest until fall when cooler temperatures could enhance fruit set and quality. Three meter plots, either of 'Prime-Jim®' or 'Prime-Jan®', were initially mowed to ground level on 30–31 March 2010. Three replicate plots of each variety were then either mowed once on May 24 or mowed on May 24 and then again on July 6. Percent flowering canes and number of ripe fruit per plot were determined weekly. Mowing in May delayed flowering by approximately two weeks in both 'Prime-Jim®' and 'Prime-Jan®' plants. When primocanes were mowed in March in either variety, ripe fruit production peaked between 19–20 weeks after mowing. When primocanes were mowed in May in either variety, ripe fruit production peaked between 21–22 weeks after mowing. Mowing primocanes in July for either variety delayed growth and primocanes did not flower. Extremely hot summer and fall temperatures coupled with drought conditions starting in August and extending into the fall likely negatively impacted all treatments, especially plots that were mowed in May and July.

Stink Bug Species Associated with Organic Blackberry Production in Kentucky. MARQUITA L. GRAYSON-HOLT*, JOHN D. SEDLACEK, KAREN L. FRILEY, KIRK W. POMPER, JEREMIAH D. LOWE, MICHAEL K. BOMFORD, CHRISTOPHER M. WALES, RACHEL S. HAYDEN, and SHERI B. CRABTREE, Atwood Research Facility, Kentucky State University, Frankfort, KY 40601.

Stink bugs (Hemiptera: Pentatomidae) are pests of organic blackberries in Kentucky. Brown, one spotted, green, and other species of stink bugs cause damage directly by feeding on blackberry drupelets, discoloring fruit and imparting foul odors. Populations of these insects and organic management tactics have not been studied in Kentucky blackberry crops. Strategies to delay primocane growth, such as spring mowing of primocanes, on primocane fruiting blackberry varieties could delay fruit set and avoid stink bug attack. Three meter plots either of 'Prime-Jim®' or 'Prime-Jan®' were initially mowed to ground level on 30–31 March 2010. Three replicate plots of each variety were then either mowed once on May 24 or mowed on May 24 and then again on July 6. Stink bugs were sampled weekly by hand picking from blackberry bushes and with 232 cm^2 yellow sticky traps. Species caught were the brown stink bug, *Euschistus servus*; one spotted stink bug, *E. variolarius*; green stink bug, *Acrosternum hilare*; twice stabbed, *Cosmopepla lintneriana*; rice, *Oebalus pugnax*; and the red shouldered stink bug, *Thyanta custator*. The brown stink bug was the most abundant species caught followed by the green stink bug and rice stink bug with 38%, 17% and 15% of the total number captured, respectively. One spotted and twice stabbed stink bugs each accounted for 14% and the red shouldered stink bug represented less than 3% of the total number caught. Almost all ripe fruit, approximately 70%, harvested from both cultivars showed some feeding damage on berry drupelets.

Populations of Beneficial Insects in Conventionally Grown Sweet Corn Using Methyl Salicylate Based PredaLure® Lures. RACHEL S. HAYDEN*, JOHN D. SEDLACEK, KAREN L. FRILEY, CHRISTOPHER M. WALES, and MARQUITA L. GRAYSON-HOLT, Atwood Research Facility, Kentucky State University, Frankfort, KY 40601.

Sweet corn, *Zea mays* 'Garrison®', was grown in 30 m long × 12 m wide replicated plots on the University of Kentucky's Horticultural Research Farm. Yellow sticky traps 15 cm × 15 cm were used to capture insects and examine efficacy of PredaLure® within the plots. Six lures were deployed in each plot on August 24 and stapled to a tobacco stick at crop canopy height. Two lures were deployed in the center of each plot and one in the center of each quadrant of each plot. One sticky trap was deployed at the same location as each lure and stapled to the tobacco stick at ear height. Traps were changed weekly through anthesis. Sticky traps were placed individually in ziplock plastic bags, labeled, and transported to the laboratory for insect identification and enumeration. Pink lady beetles, *Coleomegilla maculata*; Asian lady beetles, *Harmonia axyridis*; spotless lady beetle, *Cycloneda munda*; seven-spotted lady beetle, *Coccinella septempunctata*; big eyed bug, *Geocoris punctipes*; green lacewing, *Chrysoperla carnea*, and brown lacewing; *Hemerobius* sp. were the predatory insects collected. Pink lady beetle, big eyed bug and the green lacewing represented 87%, 6% and 3% of the total beneficial insects caught, respectively. The remaining species represented 4% of the total. Pink lady beetle was twice as abundant in non-baited plots as baited plots. However, there was a tendency toward higher numbers of Asian lady beetles, spotless lady beetles, big eyed bugs, minute pirate bugs, green lacewings and brown lacewings in plots where PredaLure had been deployed.

ANTHROPOLOGY AND SOCIOLOGY

Early Experiences with Vegetable Consumption and Current Body Weight Status of Kentucky Adults. RAMONA DOUGLAS*, CHANGZHENG WANG, LINGYU HUANG, and CECIL BUTLER, Human Nutrition Program, Kentucky State University, Frankfort, KY 40601.

Low consumption of vegetables may be one of the major reasons for the obesity epidemic in the United States. The objective of the project was to determine how experiences with vegetable consumption in early life might affect vegetable consumption and body weight status of adults. Visitors to the 2009 Kentucky State Fair were recruited to fill out a questionnaire before they were given a free analysis of their body composition (body fat %) with a Tanita TBF-521 body composition analyzer. Among the 200 participants, 69% were female and 31% were male; 88% were Caucasian and 9% African Americans. Majority of the participants had positive views of milk and vegetables. Among the people surveyed, over 90% of them prefer fresh vegetables. When they were young, 44% of them were allowed to eat whatever they liked, 41% were given a fixed amount of vegetables to eat, 17% of them were forced to eat vegetables, but nearly 10% had no vegetables. Those who ate whatever they liked during early life had significantly higher proportion of people classified as overweight or obese, compared to those who were given a fixed amount of vegetables during early life. These results indicate that how vegetables were introduced during early life may have serious consequences for the body weight status of people in their adult life.

Bad College Habits: Who is to Blame? SAMANTHA WANG*, College of Agriculture, University of Kentucky, Lexington, KY 40506.

The start of college life is associated with unhealthy eating habits. It is not clear whether such habits are the results of changes associated with college life, such as stress and boredom, late night snacking, a need for convenience, and the availability of unhealthy food choices on the college campus. The objective of this study was to determine how eating habits formed before college may influence food choices and eating habits of college students. A questionnaire was administered to 71 resident freshmen attending the University of Kentucky on a minimum meal plan to examine their food choices and eating and activity habits in relation to their body mass index (BMI) before college and during the first semester of the freshman year. Overall, all students' food choices and eating habits became less healthy upon attending college, regardless of their family food choices and eating habits. However, students who had healthier food choices and eating habits while living with their family were significantly healthier than students who had less healthy food choices and eating habits while living with their families. These results demonstrated the importance of training children to eat healthy before they go to college.

Major Nutrition and Health Concerns among People Living in Rural Kentucky. CHANGZHENG WANG*, CECIL BUTLER, and LINGYU HUANG, Human Nutrition Program, Kentucky State University, Frankfort, KY 40601.

People living in rural areas may not have the same level of nutrition and health services available to urban populations. In addition, they may not be quite as concerned as people living in the urban areas. The objective of this project was to understand the major nutrition and health concerns of rural populations so service projects might be developed to meet their needs. Visitors to the Kentucky State University's field day were recruited to answer a questionnaire about their current body weight, health status, and their major nutrition and health concerns. Among the 50 participants, over 60% were female, majority of them were over 40 years old,

over 65% were either overweight or obese and 64% live in rural areas. Fifty percent of people living in rural areas think the nutrition information in public media is confusing, compared with 20% of people living in urban areas. Sixty percent of people living in the rural areas grow their own vegetables. The top nutrition and health concerns for them are diabetes, obesity, alcoholism, cardiovascular disease, and cancer. These results indicate that there is a need to emphasize nutrition and health information related to diabetes, obesity and alcoholism in programs aimed at promoting wellness among rural populations.

Delivery of Chinese Dance Curriculum in a Summer Camp for School Children. CHERYL PAN*, Department of Curriculum and Instruction, University of Kentucky, Lexington KY 40506.

Chinese cultural dances are unique in the music and movements compared with western dance forms. They play a major role in Chinese people's lives, especially when celebration is held for holidays such as the Moon Festival and the Chinese New Year. Exposure of young people to the dances is very important to their understanding of the Chinese culture. Even though artist residency programs are helpful in that regard, lack of funding has forced many schools to eliminate the residence program. The objective of this project was to explore alternative approaches and setting to deliver Chinese dance programs to school children. In the summer of 2010, twenty children, 5–13 years old, were recruited locally to participate in a two-week summer camp focused on Chinese dances. In a series of classes, we introduced the history, cultural significance and the technical aspects of Chinese dances to the children. Many dance costumes and props plus other artistic articles were made available for the students to observe and to try themselves. Based on the student interest, they were divided into small groups to learn and practice six traditional dances such as the fan dance, ribbon dance or other ethnic dances. During the middle of each week, a field trip was made to a local park for some outside activities and to perform dances they learned. At the end of the program, a public performance was presented with parents and others interested in Chinese dances in the audience. A survey was distributed to collect opinions of the students about the quality of the program and the instructor, and their suggestions for improvement in the program. Data from 20 surveys were analyzed. All the students ranked the program 4 or 5 on a scale of 1–5, where 5 means excellent. The parents would be willing to pay for even higher camp fees if necessary. All the children would like to participate in a similar camp if it is offered again. These results indicate that school children in general are very interested in Chinese dances. A summer camp focused on Chinese dances is a feasible option for delivery of Chinese dance education curriculum for school children.

BOTANY

Somatic Embryogenesis Induction of Needle Palm (*Rhapidophyllum hystrix*). LA'QUIDA, BOWIE*, and LI LU, Community Research Service, Land Grant Program, Kentucky State University, Frankfort, KY 40601.

The development of *in vitro* regenerative protocols for needle palm (*Rhapidophyllum hystrix*) has direct applications for clonal mass propagation and conservation of this rare plant species. Needle palm is important for its ornamental value and is rare and slow in natural reproduction. Somatic embryogenesis, as a main technique for *in vitro* plantlet regeneration, has not been reported for needle palm. This project aims to: 1) Induce somatic embryogenesis from zygotic embryos of needle palm; and 2) Induce somatic embryogenesis from young leaf tissues or shoot meristem tissues of needle palm. This project has both economical and scientific significance, and it will help the conservation of endangered wild needle palm population. Needle palms seeds have been purchased and tested for their germinating rates. At present, there is no seedling germination. About ~60% of the seeds cannot find embryos after dissection. The result matched with previous reports that the germination of needle palm seeds is extremely long (6 months to 2 years), and the germination rate is low (~10%). Thirty embryos have been placed in series of media to induce germination and somatic embryogenesis. They show some enlargement but no obvious callus formation at present.

CELL AND MOLECULAR BIOLOGY

Generating Unique Chromosome Sequencing Probes to Observe Telomere Instability in *Magnaporthe oryzae*. KELLI CHATMAN-MIMMS*, MARK L. FARMAN, and OLGA NOVIKOVA, Department of Plant Pathology, University of Kentucky, Lexington, KY 40546.

Telomeres are repetitive DNA regions at the end of chromosomes that provide protection against chromosome degradation and end–end fusion. If instability occurs, chromosome deletion and shortening occurs during the end replication process, which can lead to cell aging and cancer. In this experiment we use *Magnaporthe oryzae*, a fungus that causes serious pathogenic cereal diseases, as our model to observe telomere instability. The goal of the project was to understand how MoTeRs cause telomere instability and if they have a role in telomere maintenance. MoTeRs are retrotransposons that insert specifically into telomeric DNA and are unique to *M. oryzae*. Within the project, my specific objection was to develop four hybridization probes that would allow us to monitor specific (MoTeR-containing) telomeres of LpKY97-1A, which is known to show telomere instability in *M. oryzae*. The chromosomal sequences near MoTeRs in Strain FH were tested to see if they were also adjacent to MoTeRs in LpKY97-1A. If these sequences were adjacent in LpKY97-1A, then those sequences were used to monitor instability of the corresponding telomeres in LpKY97-1A. Before testing if chromosomal sequences

were adjacent to MoTeRs in LpKY97-1A, four MoTeR-containing clones from FH (control) were analyzed by using primers, short nucleic acid for DNA synthesis, and running PCR experiments to amplify those regions. Once amplification of these regions worked in FH, PCR was then run with this same set of primers on LpKY97-1A. Overall, the results confirmed that only one of the clones showed a MoTeR adjacent to the telomeric repeats in LpKY97-1A, while the others remain inconclusive.

COMPUTER AND INFORMATION SCIENCES

Avatar Face Detection Analysis using an Extended Set of Haar-like Features. DARRYL D'SOUZA*, and ROMAN V. YAMPOLSKIY, Department of Computer Engineering and Computer Science, Speed School of Engineering, University of Louisville, Louisville KY 40292.

Criminal activity in virtual worlds is becoming a major problem for law enforcement agencies. In this work a set of standard algorithms capable of detection of avatar faces with high degree of accuracy is evaluated. Specifically, Viola-Jones machine learning approach for visual object detection, based on a boosted cascade of simple features, which is capable of processing images extremely rapidly and achieving high detection rates is evaluated. Additionally, a set of improvements proposed by Lienhardt et al. based on a novel set of rotated features, which significantly enrich the basic set of simple haar-like features is also considered. In the reported experiments we detect frontal avatar faces collected in Second Life virtual community and analyze the results in terms of false errors (27%) as well as achieved overall accuracy (73%). The obtained accuracy rate indicates that forensic tracking of avatar faces in virtual worlds is possible but additional work is necessary to improve the accuracy of the available algorithms. In our future work we plan to develop automated solutions based on facial color profiles for a number of scenarios related to avatar authentication, including: matching of an avatar representing the same person from different virtual worlds and developing a multimodal system capable of authenticating both biological (human being) and non-biological (avatars) entities.

ECOLOGY AND ENVIRONMENTAL SCIENCE

Comparison of the Neotropical Migrant Breeding Bird Communities of the Preserve and Recreation Areas of John James Audubon State Park, 2004–2007. MICAH W. PERKINS*, Division of Mathematics and Science, Owensboro Community and Technical College, Owensboro, KY 42303.

Neotropical migrant birds that breed in Kentucky's forests are of conservation interest due to wintering ground loss, fragmentation of temperate forests, nest predation and nest parasitism by brown-headed cowbirds (*Molothrus ater*). John James Audubon State Park is one of seven Kentucky State Parks with State Nature Preserves within their boundaries. I was interested if the preserve section provided a better quality habitat for Neotropical migrant birds in terms of diversity than the recreation area of the park. I surveyed bird populations during the breeding season from 2004 to 2007. Total Neotropical migrant diversity was similar between preserve and recreation areas but I noted differences in diversity based on habitat use and mean bird community conservation value. Brown-headed cowbird levels were similar across the park. The preserve and recreation areas of John James Audubon State Park provide a sanctuary for forest breeding Neotropical migrant birds in human-dominated landscape.

Energetic Cost of Immune Response in Old-Field Mice, *Peromyscus polionotus* (Osgood). CALLIE L. WILSON*, ERIN E. KEENEY*, and TERRY L. DERTING, Department of Biological Sciences, Murray State University, Murray, KY 42071.

The immune system is critical to survival and subsequent reproductive success of organisms. Researchers have suggested that components of the immune system, especially adaptive immunity, are energetically expensive. Our goal was to quantify the cost of the immune system to determine whether trade-offs in energy use occur between branches of the immune system and between the immune system and other physiological processes during an immune response. We tested the null hypothesis that an ongoing humoral immune response has no effect on the development of a cell-mediated immune response. Using adult male old-field mice, *Peromyscus polionotus*, we induced cell-mediated responses in cell-mediated/humoral (CH; $n = 10$) and cell-mediated (Cm; $n = 10$) mice using dinitrofluorobenzene, and a humoral response using sheep red blood cells. Results were compared with control mice (Ct; $n = 10$). We measured the energetic cost and strength of the immune responses through analysis of daily metabolic rate, resting metabolic rate, blood cell counts, pinnae measurements, and hemagglutination assays. Metabolic rates of the CH and Cm mice did not differ significantly from those of Ct mice, despite significantly smaller masses of immune and vital organs in the latter group. There was an unexpected significant increase of innate activity in CH mice compared to Ct mice. In addition, we failed to find significant difference between the Cm and CH groups in any measured parameter. Thus, our work showed no significant trade-offs between the humoral and cell-mediated immune systems. Our results also did not support the widely used assumption of a high energetic cost of adaptive immunity.

GEOLOGY

Examination of a Tabulate Coral Biostrome in the Bull Fork Formation (Ordovician), Bath County, Kentucky. ANN W. HARRIS*, and ROBERT T. LIERMAN, Department of Geography and Geology, Eastern Kentucky University, 521 Lancaster Avenue, Richmond, KY 40475.

This project examines a Late Ordovician reef complex that is exposed along Interstate 64 in Bath County, Kentucky. The reef examined consists mainly of tabulate

corals of the genus *Tetradium*. Research methods, analyses, and interpretations assisted in determining: (1) the environmental conditions under which this reef first established itself, (2) how it evolved or developed, and (3) what led to its demise. There are five distinct lithofacies that make up this tabulate coral buildup. The section begins with a series of interbedded shales and limestones (Facies A). Lying directly over this unit is Facies B, a fossiliferous packstone that was deposited during a storm. This layer of debris is thought to have provided the hard, relatively stable surface that was initially colonized by the tabulate (*Tetradium*) corals making up the biostrome. The biostrome itself (Facies C) lies directly on this storm lag. The lower half is dominated by club-shaped ramose, and hemispherical forms that have been knocked over, and in many cases, completely overturned. Scattered between clusters of corals and capping many of the colonies is Facies D, a grainstone to coral rudstone/floatstone. This unit was deposited as carbonate sands (grainstone) that washed in-between individual coral heads within the biostrome. The biostrome is overlain by a layer of terrigenous mud (Facies E) that buried this developing reef system. The mass of terrigenous mud that overwhelmed the system was derived from the erosion of the Taconic highlands in eastern Pennsylvanian and New York.

HEALTH SCIENCE

Antioxidant Activity of Primocane Fruiting Blackberries Grown in Kentucky. LINGYU HUANG*, CHANGZHENG WANG, CECIL BUTLER, JEREMIAH D. LOWE, and KIRK W. POMPER, Atwood Research Facility, Land Grant Program, Kentucky State University, Frankfort, KY 40601.

Primocane fruiting blackberries have the potential to produce a niche-market crop for Kentucky growers from late summer until frost. In June 2006, six selections of primocane fruiting blackberries from the University of Arkansas breeding program (APF-27, APF-40, APF-41, APF-42, APF-46, and APF-77) and the commercially available primocane fruiting cultivars Prime-Jim® and Prime-Jan®, were established at the Kentucky State University (KSU) Research Farm. The objective of this project was to determine if there are differences in antioxidant activities among these blackberry cultivars. Mature blackberries were collected from the experimental station at Kentucky State University. Each group was homogenized and analyzed for dry matter and ash content. The acetone extracts of the samples were analyzed for total phenol content according to the Folin-Ciocalteu assay using gallic acid as the standard and antioxidant capacity by FRAP assay with trolox as the standard. Prime Jan cultivar had the highest total phenol content and antioxidant capacity among the cultivars tested, whereas the A40 cultivar ranked the lowest in those measurements. These results indicate that antioxidant activity varies among blackberry cultivars. It is desirable to select cultivars with high antioxidant activity for their nutritional benefits.

PSYCHOLOGY

Preliminary Data on the Test-Retest Reliability of the Acceptance and Avoidance Questionnaire for Depression. BOBBY F. FITZPATRICK*, DAVID Z. PORTER, JEFFREY DOBSON, JOHN BLACKLEDGE, and SEAN P. REILLEY, Department of Psychology, Morehead State University, Morehead, KY 40351.

This study reports the preliminary one-week test-retest reliability of the Acceptance and Avoidance Questionnaire for Depression (AAQ-D) in a non-clinical, university sample of 53 undergraduates. Additionally, correlations between the AAQ-D and previously validated, related instruments are reported. The potential implications for use of the AAQ-D as a theoretically derived Acceptance and Commitment Therapy process measure that targets core aspects of depression are discussed.

Preliminary Data on the Use of the M-FAST to Assess Malingered AD/HD. KELLY D. GRUBER*, and SEAN P. REILLEY, Department of Psychology, Morehead State University, Morehead, KY 40351.

Attention Deficit/Hyperactivity Disorder (AD/HD) is a common mental disorder characterized by inattention, and/or hyperactivity/impulsivity. There is concern about malingered AD/HD among adults because of the availability of credible, web-based information on AD/HD and attractive secondary gains for malingering. AD/HD rating scales are widely used as part of an assessment for AD/HD. However, previous studies have indicated that adults can successfully malinger AD/HD on a majority of attention rating scales. This study presents preliminary data on the ability of the Miller Forensic Assessment of Symptoms Test (MFAST), a 25-question structured interview, to detect malingered AD/HD. Using a simulation design, 18 college students with and without enhanced knowledge of AD/HD were randomly assigned to malinger AD/HD and were compared to controls on the MFAST and attention rating scales. The findings are discussed in relation to use of the MFAST as an aid to screen for malingered AD/HD. This research was supported by a Morehead State University Undergraduate Research Fellowship and a prior grant from KY EPSCoR.

Preliminary Data on the Impact of AD/HD Malingering on the Digit Vigilance Test. MEDINA JACKSON*, and SEAN P. REILLY, Department of Psychology, Morehead State University, Morehead, KY 40351.

Attention Deficit/Hyperactivity Disorder (AD/HD) is a neuropsychological disorder involving hyperactive/impulsive behavior and inattention. Attention rating scales completed by the client or a collateral and neuropsychological tests of attention are tools commonly used to assess and diagnose AD/HD. Research has shown that attention rating scales are highly susceptible to malingering whereas neuropsychological tests are less susceptible to feigned AD/HD. The current study provides preliminary data on the susceptibility of the Digit Vigilance Test to malingered

AD/HD. The DVT is a theoretically anchored paper-and-pencil test of visual sustained attention that has good applicability to a variety of neuropsychological disorders. Using an experimental approach, 17 college students with and without enhanced knowledge of AD/HD were randomly assigned to complete the DVT honestly or as someone attempting to feign AD/HD. The findings are discussed in relation to the utility of the DVT as a measure of visual sustained attention for clinical AD/HD assessment. This research was supported by a Morehead State University Undergraduate Research Fellowship and a prior grant from KY EPSCoR.

SCIENCE EDUCATION

Was it Something I Said? Laughter and Tears in Biology. JOHN G. SHIBER*, Division of Nursing, Science and Allied Health, Big Sandy Community & Technical College, Prestonsburg, KY 41653.

Three hundred forty student responses to Fill-in-the-Blank (FIB) and Short Answer (SA) questions appearing on the first two of four introductory biology tests were reviewed and categorized as Correct (C), Partially Correct (PC), Incorrect (I), or No Answer (NA). The percentages of answers falling into each category were then calculated and compared according to question type. Among questions having the potential for PC answers, SA questions received 17% more PC responses than the FIB ones, but the latter type had 19% more C answers. Considering all questions of both types there was little difference between percentages of correctly answered FIB and SA questions (28% and 32%, respectively) or I/NA responses (72% and 68%, respectively). This indicates that questions in introductory biology tests at the community college level requiring straightforward, written answers are difficult for the majority of students. If they comprehend the material, it is clear that they have not learned it sufficiently well to verbalize it. Giving them opportunity to 'guess' answers in order to pass tests, via abundant True/False, Matching, and Multiple Choice questions, is counterproductive to the learning process. It is suggested that colleges and universities 1) focus as much on retention as they do on recruitment; 2) instate science courses in developmental program curricula to give ill-prepared students the background needed to successfully complete introductory-level biology courses; and 3) create a mandatory orientation course for first year students on how to take notes, memorize essential terms, and improve study habits. On the instructional level, students might be given increased in-class opportunity to write about concepts being discussed, outside the context of testing.

Educational Opportunities in Biotechnology and Other STEM Areas at Kentucky State University. LI LU[1]*, KIRK W. POMPER[1], and KARAN KAUL[2], [1]Community Research Service, Land Grant Program, Kentucky State University, Frankfort, KY 40601, [2]Carver Hall, Kentucky State University, Frankfort, KY 40601.

Modern biotechnology impacts multiple areas of natural sciences, like medicine, genetics, biochemistry, cell biology, and agriculture. Training in biotechnology techniques and related STEM areas is critical for students who wish to pursue careers in the life sciences and agriculture. In 2008, a USDA 1890 Institution Capacity Building Grant "Creation of Summer Educational Opportunities in Biotechnology to Recruit Students and Enhance STEM Areas at Kentucky State University" was funded with the objectives to 1) Create summer biotechnology workshops for K-12 students by providing "hands on" training in modern molecular techniques and scientific methods; 2) Implement summer biotechnology workshops for K12 teachers and non-traditional students; 3) Create summer and fall BIO 410: Special Problems in Biology course at KSU in learning techniques of biotechnology through undergraduate student research projects, and enhance the implementation of BIO 495 Biotechnology courses with new techniques. Totally ~200 participants have already participated in workshops and classes supported by this grant. The workshop participants acquired an understanding of modern biotechnology, most recent progress in high-technology agriculture, possible careers in agriculture and STEM areas, etc. through lectures. They also performed series of safe, easy-to-understand experiments concerning yeast fermentation, DNA finger printing, and Genetic Modified Organisms. The attendees enjoyed the process and expressed interests in related/advanced workshops. The undergraduate students of KSU have gained opportunities through BIO410 course to learn and apply modern biotechnology techniques to various research projects.

J. Ky. Acad. Sci. 71(1–2):111–112. 2010.

Kentucky Academy of Sciences Governing Board Meeting Northern Kentucky University Student Union 14 November 2009

The 2009 KAS Annual Business Meeting was called to order by President Robin Cooper at 5:30 P.M. Fifty-five KAS members and guests were in attendance.

President's Report

Dr. Cooper welcomed the KAS membership and thanked Northern Kentucky University for their hospitality.

President Elect's Report

President Elect Nancy Martin addressed the membership and noted this is the largest Annual Business Meeting in recent history, if not of all time most likely due to scheduling the meeting prior to the Awards Banquet. President Elect Martin requested input from the membership regarding any KAS issues they would like her to address during her term as KAS President. During 2010 Dr. Martin would like KAS to be the Voice of Science in Kentucky.

Treasurer's Report (handout filed with minutes)

Ken estimates for the 2009 KAS budget will end with approximately $107K in revenue and $106K expenses for a positive end of year balance.

Total current assets for Athey Trust account and the Wachovia savings account are approximately $1.4 million yielding approximate income of $50K in 2009. For new KAS members, Ken gave a brief overview of the Athey Trust.

Executive Director's Report

Jeanne Harris reported KAS membership is now 1869 and this is a dramatic increase over the past four years. KAS Annual Meeting pre registrations was also a record 756.

JKAS Editor Report

David White was not able to attend. Robin Cooper shared a motion approved by the Board at the November 13 board meeting increasing the page charge rate for the JKAS to $40/page for KAS members and $50 for non members beginning with Volume 71.

KJAS Executive Director Report

Ruth Beattie reported the KJAS Annual Meeting will be April 17 at the University of Kentucky. She requested support from the membership in serving as judges for this event.

Newsletter Editor

Susan Templeton encouraged the membership forward to her information for the KAS newsletters.

Committee on Distribution of Research Funds

George Antonious reported he has received a large number of proposals for KAS research grants.

Legislative Committee Chair Report

Blaine Ferrell reported the Kentucky Department of Education, working with the Council for Post-secondary Education, is developing state standards in mathematics as a first priority, with literacy and other sciences to follow. They are working toward a narrower focus of topics and greater depth of understanding by students (as opposed to rote memorization). Dr. Ferrell believes the department has a wealth of good data to work from, but stated that attainment of the math/science goals is not yet assured.

Dr. Ferrell said there are some other bills working their way into this legislative session that KAS should follow closely. The legislature is trying to make general education homogeneous throughout the public universities in the Commonwealth in order to promote transferability of courses. The rationale is that transferability will help more students graduate in four years. He has not seen the final draft of this bill yet, but promised to keep us informed.

2009 KAS Board Member Election Results

Sean Reilley, Chair of the Nominations shared the 2010 KAS Governing Board election results:

-At Large Representative-Mary Janssen, KCTCS
-Biological Sciences Representative-Ron Jones, Eastern Kentucky University
-Vice President –Dawn Anderson, Berea College

Recognition of Outgoing Board Members

Robin Cooper thanked George Antonious for his outstanding service to KAS. Outgoing board members, Sean O'Keefe and John Mateja were unable to attend but their service to KAS was also acknowledged at the Annual Business Meeting.

President Elect Nancy Martin thanked President Robin Cooper for his service over the past year and presented a plaque to him from the Academy. Robin Cooper assed the KAS Presidential gavel to Nancy Martin, and presented the traditional $100 gift to the President's Fund as his final act of service to KAS.

Meeting Adjourned at 6:15 P.M.

Respectfully submitted,

Rob Kingsolver	Jeanne Harris
KAS Board Secretary	KAS Executive Director

J. Ky. Acad. Sci. 71(1–2):113–115. 2010.

Kentucky Academy of Sciences Governing Board Meeting Western Kentucky University 12 November 2010

The 2010 KAS Annual Business Meeting was called to order by President Nancy Martin at 3:30 P.M.

Attending

Board and ex officio members: Nancy Martin (President), Barbara Ramey (Pres. Elect), Dawn Anderson (Vice President.), Robert Kingsolver (Secretary), Ken Crawford (Treasurer), Bob Creek, Cheryl Davis, Dick Durtsche, Mary Janssen, Eric Jerde, Ron Jones, Sean Reilley, Claire Rinehart, K.C. Russell, Susan Templeton, Judy Voelker, David White, and Jeanne Harris (Executive Director), and Jennifer Myka (Chair of Science Education Committee)

Financial Report from US Bank

James Acton reported on the status of the Athey trusts. He began by explaining the history of the four Athey trusts, reminding the Board that three of the four original trusts have been consolidated into the KAS fund, with the fourth still maintained for Raymond Athey. Mr. Acton also emphasized that the KAS investment guidelines as well as the trust provisions were being followed in the investment of the KAS portion of the funds.

The value of the Athey fund stands at $842,389 as of 10/31 of this year. Distributions next year are anticipated to be approximately $18,000, matching the 2010 performance. After some discussion of adjustments to our portfolio distribution, and on the recommendation of the Treasurer, the Board agreed to maintain the current asset distribution.

Financial Report from Wells Fargo

John Ridley and Derek Hull reported on the Academy's investments formerly called the "Wachovia Account," which is now invested through Wells Fargo. Current value of our portfolio is $481,839, and returns have recovered somewhat from the recession period, with a reported year to date growth of 4.74%.

Ridley and Hull distributed a proposal for a revised investment policy for the Board's consideration, which would make our guidelines more specific. The Board asked the Finance committee to review the proposal, and to make recommendations at the spring meeting.

Approval of Minutes

Minutes of the 7 August 2010 KAS Board Meeting were approved.

President's Report

Nancy Martin welcomed the Board, and thanked our board members and ex officio members for their work during the year.

President Elect's Report

Barbara Ramey reported that the plenary program would consist of a panel discussion on skills required for careers in science. To keep the awards banquet reasonably short, we will not have a banquet speaker this year. The Kentucky Tennessee Branch of the American Society for Microbiology, meeting in conjunction with KAS this year, is providing the Friday evening speaker.

Barbara Ramey requested that the first meeting of the spring be scheduled for February 12, since she plans to travel out of state during January. Some questions were raised whether the by-laws require a January meeting, but the Board approved February 12, provided this date is not contrary to rules established in the KAS Constitution.

Treasurer's Report (handout filed with minutes)

Ken Crawford reported that the financial picture has brightened somewhat this year. The Wells Fargo account has out-performed inflation since 2004, with a current balance of $504,000. Even so, the downward trend in endowment income has resulted in a projected $7K deficit for 2010. The situation is not

dire, but will require attention in the coming year. Ken stated the NUCUBO payout distribution rate is 4.3% and he proposes a 3.5% distribution of the corpus for income during 2011. Eric Jerde moved to accept Ken's proposal and was passed by the Governing Board. The Academy has covered recent shortfalls in the budget by spending down cash on hand, but this approach is unsustainable over the long term. We will need to reduce expenditures, or increase income. The Board discussed several options, including reducing the research grant pool, or charging students a modest amount to attend the banquet. (This was deemed a prudent response to the high "no-show" rate we have experienced in recent years.) The Board finally decided to conduct a fundraising campaign to underwrite undergraduate research projects. Taking the onus of undergraduate research grants off the general fund has the potential to close our budget gap. Nancy Martin agreed to take the lead in pursuing this objective.

Secretary's Report

Rob Kingsolver suggested that Academy members might do more to communicate information from science and about science to non-scientists, particularly those holding leadership positions in business and government. A suggestion that emerged from ensuing discussion was that we could post public talks and other forms of science education outreach on our web site.

Vice President's Report

Dawn Anderson requested more nominations for superlative awards next year—there are few nominations in the files to begin working from in 2011. Dawn stated the nomination criteria of 4–5 letters of recommendation maybe a deterrent to the nomination process and moved that the number of letters of recommendation for the Superlative Nominations be changed to 2–3 instead of 4–5. This was passed by the board.

Planning Committee

On the Past President's behalf, Jeanne Harris reported that next year's KAS meeting is being planned for November 4 and 5 at Murray State University.

Program Coordinator's Report (handout filed with meeting minutes)

Bob Creek reported that this year's meeting had attracted a healthy number of talks and posters, but that rewriting abstracts submitted at the last minute remains a challenge. There were 233 talks presented this year (30 more than last year), and 211 posters (22 more than last year).

A suggestion generally approved by the Board was that abstracts be submitted on-line, with fields for critical authors' information automatically populated from registration data.

Ron Jones expressed a concern that there were too few faculty talks presented in our section meetings, saying that he does not want the Academy to become an exclusively student-based organization. In following discussion, the Board acknowledged the growing pressure on non-tenured faculty to present at national rather than state meetings. For state researchers outside of academe, the lack of travel funds for state employees was also identified as a problem. Several Board members recalled that symposia focused on particular topics or issues have resulted in higher rates of professional contribution in the past.

KAS Newsletter Editor

Susan Templeton said the newsletter would be coming out in January, ahead of the first Board meeting of 2011. She requested that a letter from the incoming President, and other articles for the Newsletter, be submitted to her by December 15.

KJAS

Ruth Beattie sent word that she has scheduled the Junior Academy science competition for April 23. In keeping with longstanding practice, the KAS Board is expected to synchronize its meeting with KJAS so that our members can provide judges for the student competitions. Several members of the Board expressed objections to the chosen date, since April 23 is the Saturday falling between Good Friday and Easter. In her message, Ruth Beattie acknowledged this conflict, but offered the rationale that the previous two weekends fell on spring breaks for some school systems.

Journal Editor

David White reported that only one issue of the KAS Journal would be printed this year, due to a dearth of high quality manuscript submissions. To solicit more manuscripts, Nancy Martin suggested that she could invite faculty who had presented talks at the meetings to write up their findings to submit to the Journal.

David White announced that he will step down from editing the journal at the end of next year, but is willing to work with anyone willing to assume responsibility for the journal afterward. The Board members praised the improvements David has made to the Journal, and expressed regret at his departure as editor. Barbara Ramey said finding a new journal editor to carry on David's excellent work would be an important item on the Board's agenda next year.

Executive Director's Report (handout filed with meeting minutes)

Jeanne Harris reported that the enhanced affiliate program continues to bolster membership in the Academy with current membership at 2288. Georgetown College has joined KAS as a new Enhanced Affiliate. Overall, the 2010 online pre registration went well with a record 696 pre registrations. Additionally, with the help of Blaine Ferrell and WKU, KAS secured 10 meeting sponsors/ $3650 in revenue for the 2010 meeting. Exhibitor revenue was $1350 which is down from previous years due to low traffic in exhibitor areas leading vendors not returning.

On behalf of the Nominations Committee, the Executive Director reported election results:

Judy Voelker was re-elected as representative of Social and Behavioral sciences.

Eric Jerde was re-elected as representative of Physical Sciences.

Cheryl Davis was elected Vice President.

Web Editor

Claire Rinehart reported the on-line meeting registration seemed to work well.

Division Representatives

Posters at the Capitol is being planned for February 10, 2011.

Distribution of Research Funds

Our current practice requires grant proposals to be submitted on 7 CDs. This is deemed onerous and unnecessary, so the Board voted to change our process to electronic proposal submissions. Bob Creek suggested that Kathy Sauer could help make this change.

Legislative Committee

Blaine Ferrell is working with the Council on Postsecondary Education on a strategic plan, and will report back to the Board in February.

Old Business

David White took up the previous issue of opening back issues of the KAS journal to the public. The older issues are currently available on line to KAS members. His proposal was not to open access to more recent issues, which generate income for the Academy through BioOne distribution. The Board approved this proposal.

Meeting Adjourned

Respectfully submitted,

Rob Kingsolver	Jeanne Harris
KAS Board Secretary	KAS Executive Director

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INDEX TO VOLUME 71

Compiled by Ralph L. Thompson

CONTENTS